t No. FHWA-RD-77-39

S AND MARKINGS FOR LOW VOLUME RURAL ROADS

May 1977

Final Report

Document is available to the public through the National Technical Information Service, Springfield, Virginia 22161

Prepared for

FEDERAL HIGHWAY ADMINISTRATION

Offices of Research & Development

Washington, D. C. 20590

NOTICE

Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
FHWA-RD- 77-39		

4. Title and Subtitle	5. Report Date
SIGNS AND MARKINGS FOR LOW VOLUME RURAL ROADS	May 1977
	6. Performing Organization Code
7. Author(s)	8. Performing Organization Report No.
Walton, N. E., Mounce, J. M., and Stockton, W. R.	
9. Performing Organization Name and Address	10. Work Unit No. (TRAIS)
Texas Transportation Institute Texas A&M University College Station, Texas 77843	FCP 31A1-553
	11. Contract or Grant No. DOT-FH-11-8249
12. Sponsoring Agency Name and Address	13. Type of Report and Period Covered
Department of Transportation Federal Highway Administration, Office of Research Washington, D.C. 20590	Final Report
	14. Sponsoring Agency Code

15. Supplementary Notes

FHWA Contract Manager - J. True, HRS-33

16. Abstract

Warrants and guidelines for warning and regulatory signs and markings in the Manual on Uniform Traffic Control Devices (MUTCD) are evaluated for functional, economical, and aesthetical applicability to low volume rural roads (average daily traffic [ADT] of less than 400 vehicles). The research involves classifying the types of low volume rural roads and identifying driver information needs on the various classifications. Supplemental guidelines to the MUTCD based on safety, costs, and aesthetics are developed and validated.

17. Key Words	18. Distribution Statement
Low volume, rural road classification, signing and marking guidelines, safety, economy, aesthetics.	Document is available to the public through the National Technical Information Service, Springfield, Virginia 22151

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
UNCLASSIFIED	UNCLASSIFIED	145	

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

PREFACE

The present warrants and guidelines for warning and regulatory signs and marking in the Manual on Uniform Traffic Control Devices (MUTCD) do not contain specific standards for every type of road; e.g., unique criteria for low volume rural and recreational roads (average daily traffic [ADT] of less than 400 vehicles) are not available. This study employed a task analysis procedure using video and audio tape recordings taken on low volume rural roads in Texas, Arkansas, Oklahoma, and Louisiana.

Road classes were defined for the purpose of signing and marking considering both functional and design aspects. Driver information needs were identified within the constraints of economy, safety, and aesthetics. Validation of design recommendations was performed by a detailed analysis of critical areas such as cost-effectiveness of signing and marking, relative degree of risk associated with the presence or absence of signs and markings, and aesthetics in signing.

Supplemental guidelines to the Manual on Uniform Traffic Control Devices were developed to be consistent with the Manual. If readers, in reviewing such guidelines and other findings in this report, desire to apply any new (non-MUTCD) suggested signs or markings, approval should be requested from the National Advisory Committee before usage.

TABLE OF CONTENTS

TABLE OF CONTENTS (CONT.)

LIST OF TABLES

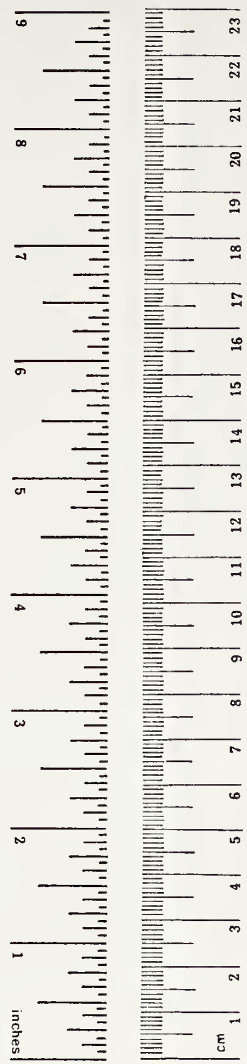
LIST OF FIGURES

METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

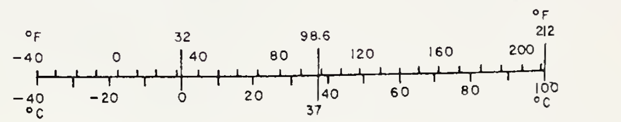
Symbol	When You Know	Multiply by	To Find	Symbol
	LENGTH			
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
	AREA			
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
	MASS (weight)			
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
	VOLUME			
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
	TEMPERATURE (exact)			
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
	LENGTH			
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
	AREA			
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
	MASS (weight)			
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
	VOLUME			
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
	TEMPERATURE (exact)			
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



INTRODUCTION

THE PROBLEM

The Manual on Uniform Traffic Control Devices (MUTCD) (20) sets forth warrants and guidelines for warning and regulatory signs and markings to be used on all classes of roadways. This application is made universally to all roads equally, i.e., freeways, arterials, local roads, and streets, both urban and rural. Such criteria for low volume rural and recreation roads (average daily traffic [ADT] of less than 400 vehicles) are not justified economically and, in many instances, may not be functionally and aesthetically desirable. Insufficient knowledge has been obtained as to the level of traffic control needed on low volume rural roads in order to maintain adequate operational guidance and safety. Past studies on this subject have generally been concerned with the higher type rather than the lower type facility. There is a need for the development of guidelines for applying traffic control devices, such as signs and markings, to low volume rural and recreation roads.

OBJECTIVES

The types of roadways under investigation in this study exhibit a wide range of both design and functional characteristics. However, foremost in all considerations is the fact that these facilities are very low volume, rural, and recreation roadways comprising a large percentage of the total highway miles under maintenance. The probability of an accident is low on these systems. The balance between safety and road economy was the foundation for pursuing the following objectives:

Literature Review -- Review all published and unpublished literature on the subject to establish an overview on the state-of-the-art in signing and marking for low volume rural roads.

Roadways Classification -- Define road classes for purpose of signing and marking with consideration toward functional aspect, design aspect, and mileage distribution.

Research Methodology and Field Data Analysis -- Analyze classes of roads and travel characteristics to determine the level of warning and regulatory signs and markings necessary for satisfactory operation and safety.

Detailed Analysis and Validation -- Validate the recommended signing and marking practices for each class of roadway by means of an analysis and discussion concerning relative degree of risk and accident potential, cost-effectiveness, and aesthetics.

Summary - Summarize study results and list any guidelines developed for signing and marking low volume roadways.

LITERATURE REVIEW

A summary of available information on signing and marking of low volume rural roads was completed and presented in March, 1974, as a state-of-the-art report by Walton and Duddlesten. Specifically, road classifications for signing and marking purposes, existing practices in signing and marking, driver information needs, and guidelines for signs and markings were discussed.

It can be concluded from the above mentioned report that, concerning the subject of traffic control on low volume rural roads, there is either an absence of correlating knowledge or this is an area of conflicting ideas and views. Much technology is available for application of signs and markings to low volume rural roads and to staying with the existing general guidelines and intent of the Manual on Uniform Traffic Control Devices. However, there is widespread discrepancy in opinions over the operative and economical efficiency of the MUTCD practices on low type facilities. This was reflected both in submitted comments by state agencies and by previous published research. Many organizations have independently drawn conclusions over the use of signs and markings on low volume rural roadways, while others perpetuate the provisions of the MUTCD for uniformity and familiarity. The research efforts in this study were directed to determine the information needs of drivers on these lower volume roads and subsequently either acknowledge the existing MUTCD as substantial or propose the necessary modifications thereof.

ROADWAY CLASSIFICATION

FUNCTIONAL ASPECT

The rural highway system encompasses a wide range of varying facilities. At one extreme is the rural freeway on the Interstate system; at the other extreme is the gravel county road leading to a farm residence. All of these public roads, whether Federal, State, or County, serve multiple functions. Their main function in rural areas is to provide access to land and dwellings; however, they also enable the government to render various essential services such as mail, fire, and police, facilitate the movement of persons and goods between communities and towns, and give access to recreation areas. Different classes of roads are devoted more to one function than to others. For the purposes of this investigation, all roads were classified according to governing agency, i.e., Federal, State and County.

Federal roads meeting the criteria of being rural and low volume consist of all facilities maintained by the U.S. Forest Service and the National Park Service. U.S. Forest service roads are broken into three basic groups: land access roads, interim development roads, and land use roads. This classification is based solely on the function the road serves. Land access roads provide access and service to all resources. Interim development roads are multi-use roadways mainly for public movement. Land use roads are built for access to a particular resource. Interim development roads may be paved or unpaved; most other roads are unpaved.

The National Park Service classifies six different types of roads with varying pavement widths and functions. The major park roads and parkways are normally wide, two-way facilities used for pleasure driving and to provide access for recreation vehicles. Minor park roads and special-purpose roads are designed for one-way operation and have limited pavement width. Interpretive, or motor nature roads are generally one-way, low speed roadways with ample parking. These roads provide scenic viewing and allow exploration of the park's natural surroundings. All of the previously mentioned roadways may be either paved or unpaved. Most National Park Service roads strive to compliment the park function, which is preservation, enjoyment, and interpretation of surrounding terrain.

Low volume, rural State highways are generally paved, higher type facilities than park or forest roads; however, there are scattered occurrences of unpaved, State-maintained roadways. In many states, this rural State highway network is classified as a State secondary system just under the State primary system. State highways serve a dual function in the rural environment in addition to providing essential government services. Their general function is as main arterials providing intercommunity mobility. This acts as a supplement to the State primary system by connecting rural towns of lesser importance than those served by the main

State highways. These roads could be considered direct branches of the primary system. A second function of rural State highways is that of collector facilities. All traffic generated on County roads either feeds directly into a town or onto a State highway.

The third functional type of roadway is the County road. These roads may be either paved or unpaved, depending upon volume and destinations. The primary function of County roads is to provide access to the outlying rural residences. In many instances, County roads also serve as mail and school bus routes. Without the County roads which act as capillaries in the highway system network, rural development, primarily agriculture, would be greatly impeded.

Varying percentages of both familiar and unfamiliar drivers travel along these roadways. The majority of Federal park road drivers are tourists with the minority being park service personnel. The two dissimilar groups of drivers, working and tourist, become more balanced on the Federal forest road with the introduction of logging activities into the traffic patterns. State highway facilities are also fairly balanced with respect to type of drivers. These roadways expedite much local traffic between small towns, but also carry through and tourist traffic. The character of the County road driver is made up almost entirely of the local, familiar resident. The function of the County road system does not often attract the unfamiliar driver.

DESIGN ASPECT

Topography is the major factor in determining the physical location of a rural highway, and generally affects the alignment, gradients, sight distance, cross sections, and other design elements. Rugged, rolling terrain often imposes limitations on location and design. In flatlands, topography may generate no design problems; however, drainage difficulties frequently occur. Considering these problems, and keeping in mind the low volumes and stringent economy, standard design criteria are very often modified or even neglected. The result is a roadway whose physical characteristics demand a lower speed of operation. This is generally true on many rural County and Federal roads because of the environment in which they are located. Most State rural highways do not fall into these categories.

Federal park and forest roadways are located and constructed in areas where it is attempted to present the surrounding terrain as natural as possible, thus producing roads with both horizontal and vertical alignment of the more severe type. Right-of-ways are normally restricted and uncleared. The side-road terrain, forests, rocks, and mountains are usually adjacent to the traveled way and can be hazardous. These roads are paved and unpaved with paved being of slightly greater width. This is not to say that these facilities are non-engineered or unsafe; the converse is true. Operationally, these facilities are safe, but only at low speeds

The driver needs no education to this fact, as it is immediately apparent. Limited roadway widths and sight distance induce the driver to lower speeds and a right lateral vehicle position on the roadway. Passing opportunities are rare to non-existent. With the low volumes found on these roads, along with the previously mentioned operational characteristics, it is apparent that the driver has ample response time to react in a safe manner whatever the driving situation.

State highways usually characterize the higher type of low volume rural roads. The predominant number of these facilities are paved with more than adequate width of roadway. Most have been completely engineered with good horizontal and vertical alignment. Sight distances are usually such that there are numerous opportunities for passing along any given stretch of road. Operating speeds may range from low, 35 mph, to moderately high, 55 mph or above. This is entirely dependent upon terrain which influences alignment and right-of-way restrictions. In many instances, right-of-ways are clear with some type of side slope design employed. The State highway is seemingly the safest of all rural roads; however, this observation must be weighed against the increase in stopping distance occuring with the higher speeds which the facility encourages. In turn, this must be balanced against the low percentage of accident occurrence associated with the low volumes found on these roadways.

From a design standpoint, County roads are a distinct and different type of roadway from those previously discussed. Any given length of roadway may motivate the driver to high speeds along tangents, then strictly require very low speeds to safely proceed through curves. These drastic speed differentials many times occur without any visual warning. This type of situation is due to the fact that these facilities were built under no engineering design standards; many times being paved along the previous unpaved road. The unexpected is the calling card of the County road. Roadway widths vary; however, in many instances, they are marginally adequate, depending upon speed. Right-of-ways are normally restricted and unclear. The County road induces a sense of safety to the driver which the alignment may or may not justify. The design function of a County road is the most difficult of all types of rural roads to identify.

MILEAGE DISTRIBUTION

For the purpose of this study, rural roadways were subdivided into the following classifications:

Paved -- Less than or greater than 20 feet
Unpaved -- Less than or greater than 20 feet

All of these roads met the general criteria of 400 ADT or less. With this type of breakdown established, the next step was to compile representative mileages for each system category. These would be presented for each individual state within the original study area.

To accomplish this task, data were obtained from the annual publication, Highway Statistics, which is prepared by the Federal Highway Administration with the cooperation of the State highway departments. Although figures were readily available from this report with respect to state and surface type, there was no further adjustment given concerning ADT or roadway width. Therefore, assumptions had to be made about the percentage of total traffic on rural Federal, State, and County facilities which would reflect that of 400 ADT or less. After carefully reviewing state wide traffic maps of Texas, Arkansas, Louisiana, and Oklahoma, it was found that virtually all Federal and County roadways in the rural environment have less than 400 vehicles per day. There were only 20% of the State highways in this class. The previously mentioned data from Highway Statistics was adjusted by these percentages resulting in a mileage distribution which reasonably applied to the study classifications. There were no statistical figures available to reflect the roadway width. The results are presented in Table 1.

Upon analysis of Table 1, several numerical conclusions are evident; however, it must be kept in mind that these figures represent 1971 totals. Slight increases in mileage could be expected at the present time for all classes of roadways. The conclusions drawn are as follows:

1. The total miles with 400 ADT or less in the four-state region is 319,676, or approximately 80% of all existing roadways, whether Federal, State, or County maintained.

2. Of the 319,676 miles in the study region, Texas accounts for 47% of the total, Oklahoma for 26%, Arkansas for 17%, and Louisiana for 10%.

3. Texas has the majority of mileage in all categories except roadways under Federal control where Arkansas is predominant.

4. Federal roadways are 93% unpaved and 7% paved. State roadways are 15% unpaved and 85% paved. County roadways are 73% unpaved and 27% paved.

Table 1. Total rural road mileage[1] classified by system and type of surface

	Rural Roadways With Less Than 400 ADT						
	Under Federal Control[2]		Under State Control		Under County Control		
State	Unpaved[3]	Paved[4]	Unpaved	Paved	Unpaved	Paved	Total
Arkansas	1,719	123	394	2,196	36,546	13,541	54,519
Louisiana	269	19	432	2,408	20,337	7,522	30,987
Oklahoma	18	12	349	1,946	59,950	22,173	84,448
Texas	931	67	1,867	10,418	99,602	36,839	149,724
	2,937	221	3,042	16,968	216,435	80,075	319,678

(1) Above data compiled from Highway Statistics, U.S. Department of Transportation, Federal Highway Administration, 1971. (19)
(2) National Parks, Forests, Reservations, etc.
(3) Unpaved includes primitive, unimproved, graded and drained roads, soil-surfaced, and slag, gravel, and stone.
(4) Paved includes any type of bituminous surface treatment, mixed bituminous penetration, bituminous concrete, or portland cement concrete.

RESEARCH METHODOLOGY AND FIELD DATA ANALYSIS

TEST SECTION

The third objective of this study was to analyze the predetermined classes of roads and travel characteristics to determine the level of warning and regulatory signs and markings necessary for satisfactory operation and safety. A modified form of driver task analysis, similar to that described in NCHRP Report #123, "Development of Information Requirement and Transmission Techniques for Highway Users," by G. F. King and H. Lunenfeld (14), was employed to determine driver information needs. This procedure required the physical on-site collection of both video and audio tape recording data. The study was limited to four states in the southwest United States with a minimum 250 miles of roadway to be analyzed. Data was collected on at least 50 miles of roadway in Arkansas, Louisiana, and Oklahoma, and approximately 100 miles in Texas. Numerous test sections were selected in each state covering all classes of rural facilities. The test sections varied in length from 0.5 - 6.0 miles.

The decision for approval of a particular section of roadway as a test site began with the acquisition of detailed traffic maps from the state highway department. These maps were reviewed and all roadway facilities in a general area meeting both the ADT and classification requirements of the study were noted. The selected roadways were then physically located and driven for data collection. It was desired not to drive through the test site previous to the actual data collection so as to obtain data from the viewpoint of a completely unfamiliar driver. The majority of the study was accomplished in this manner. The number, length, and particular characteristics of the test sections within a state were chosen considering the number of miles needed of each representative type of road classification.

All test sections within the four states were indexed for reference purposes with respect to state, tape number, section number, geographical location within the state, roadway classification, length of section, and ADT. A statement with this information was recorded before beginning a test section and upon completion.

DATA ACQUISITION

Upon selection of a roadway as a test site, the actual data collection was patterned after the methods described in NCHRP #123, yet, on a much less detailed scale. A driver and a cameraman were employed inside a test vehicle. The driver's principal task was to navigate the vehicle along the test roadway in a normal safe manner. He was secondarily responsible for regular verbal responses concerning speed and mileage reading. The driver was also encouraged to comment on any and all facets of the roadway facility and operation.

The cameraman's primary responsibility was to operate the audio and video recording equipment while the vehicle was traveling along the test section. The equipment used in both data collection and reduction consisted of a magnetic type camera, recording unit, and television monitor playback unit. The filming consisted of not only a panoramic scene of the roadway ahead, but specific signs, markings, elements of the roadway geometry or cross-section, situational conditions, or hazards were focused on in detail using a zoom lens.

The remaining and subsequent responsibility of the cameraman was to verbally offer any comments or impressions concerning any aspect of the raodway facility. Both the driver's and cameraman's comments were recorded on the film. Each of these individuals have extensive knowledge and experience in the field of highway engineering. Their comments and observations were considered a valuable part of the data collected.

DATA REDUCTION

Upon completion of a reel of film, which contains approximately 12-15 miles of roadway depending upon technical problems and speed operation, the reduction process began with the first playback of the tape. Each test section was summarized by a general description of the type of roadway and its operational characteristics. A summary of the comments made while driving was also included. A digest of summaries inclusive of all test sections is presented in Appendix A.

The viewing of a tape was used to subdivide each test section into what was referred to as "action or non-action sequences." These terms were defined for purposes of this study as the two elements composing the driving task. The driver is involved in one or the other of these two sequences at any particular time under operation of the vehicle along a roadway. An action sequence consists of a time frame of operation during which the driver is under high driver workload. This workload could be made up of positional decisions, such as lane tracking, speed maintenance and adjustment; situational decisions, such as vehicle-vehicle interactions, roadway geometry, and roadway environment; or navigational decisions. A non-action sequence, conversely, consist of a time frame during which the driver workload is minimal due to geometry, absence of traffic, or other factors along with a particular segment which introduces safety and ease of operation. Under this section of analysis, the test section of any given length of roadway become a "train" of action and non-action sequences linked continuously in various orders. The sequences "break or change" as the driving variables or operational conditions of the facility change.

With the operating speed along a test section being inconsistent and continually varying, time became the only means of referencing and interrelating the driving task sequences. This was accomplished through the use of the play back system counter. Each unit on the counter represented a time of 3.2 seconds. Each test section began at 000 on the counter and ascended throughout the designated length of roadway. An example of the sequence division and counter relation would be as follows:

- Non-Action Sequence #1 (000-006)
- Action Sequence #1 (007-010)
- Non-Action Sequence #2 (010-018)
- Action Sequence #2 (018-021)
- Action Sequence #3 (021-027)

The third viewing of a tape occurred when each test section on that tape had been completely divided into sequence identified by a starting and ending counter time. The driving function constants of a sequence, whether action or non-action, were recognized and noted. Driving function constants include roadway type, cross-section, geometrics, operating speed, and right-of-way. Inputs received by the driver were also observed and noted. The driving function inputs consist of signs, roadway markings, delineation, lateral alignment, traffic conditions, sight distance, surface condition, structures, etc. A written description of the driving situation was recorded along with any and all driving responses. The driver's and cameraman's comments within the sequence were detailed.

The final phase in the data reduction of a driving task sequence was an evaluation and concluding statement by the individual analysing the film. The evaluation was essentially a subjective judgement concerning the adequacy of the roadway within the sequence limits with respect to safety and operation. Under existing conditions, the conclusion simply stated approval of whatever signing and marking techniques were employed, denied need for such devices, or made recommendations as to what information is needed. The evaluation and conclusion was based on the following considerations:

- Information needed is not displayed.
- Information needed is inadequate or incomplete.
- Information given is in error or misleading.
- Information given is confusing or ambiguous.
- Information given is not in needed location; out of place; or not enough processing and reaction time is allowed.
- Information given is inadequate because of environmental or physical factors.
- Is the information given warranted for the safe operation of the facility?

The first six considerations are basically the same as those in NCHRP Report #123. The seventh consideration was an objective of this study.

The complete data reduction of a sequence was compiled on a form developed to serve this purpose. A sample form is included in Appendix B. These forms were headed appropriately and compiled to produce a detailed, segmented account of the actual driving tasks involved in traveling along the test roadway. The final result of this process was an extensive filing system relating the conditions existing on a given classification of road to the input-output experiences incurred in operation of that road.

RESULTS

Upon completion of the data reduction phase of the study, a summary of selected roadway parameters, along with the number and type of study sections, was prepared to give an overview of the study. Both the average and range of speeds, roadway width, and average daily traffic was calculated for the different types of roadway facilities. These figures can be found in Table 2.

Using the extensive file of roadway data and film tapes, a comprehensive review by several staff research engineers was undertaken to obtain both comments and suggestions of practice. Pictorial examples of the typical types of low volume rural roads encountered in the study region are shown in Figures 1 - 10.

Typical Roadways (Paved)

Description -- Federal

Observations in the field led to the conclusion that there seemed to be a distinct difference in types of paved federal roadways. Marking seemed to be this difference.

Marked -- These facilities generated moderately high speeds. Either a full compliment of signing was exhibited or there were none at all. Marking consisted of either a standard (MUTCD) centerline and no passing line, or only a solid yellow centerline. The alignment was fairly good. Sight distance along the roadway seemed generally adequate (Table 3). The R-O-W was generally restricted and was frequently hazardous. There was delineation on almost all of the bridges. Clear roadway width existed across bridges, and delineation was installed at many bridge sites. The majority of drivers on this type of roadway were unfamiliar (non-local).

Unmarked -- Moderate to low speeds were characteristic on these roadways. There were few information signs and either numerous warning

Table 2. General description of roadways*

	Paved State	Unpaved State	Paved Federal	Unpaved Federal	Paved County	Unpaved County
Sections	26	7	9	10	16	14
Miles	88.9	22.0	28.7	24.3	40.5	48.2
Avg. Speed (ft.)	51.9	37.5	40.6	32.5	42.8	37.5
Speed Range (ft.)	40-55	30-45	30-55	25-35	30-55	30-45
Avg. Width (ft.)	19.8	22	17.5	14.5	18.2	15
Width Range (ft.)	16-32	16-30	14-20	10-20	14-26	10-20
Avg. ADT	240	150	60	50	160	65
ADT Range	75-400	40-275	25-150	25-125	23-375	25-250

*Summarized from actual data collected at test sites.

Table 3. Restricted Sight Distances* Below Which Warning Signs are Required (Dry Pavement Values)

Operating Speed	Perception and Brake Reaction		Braking Distance on Level	Total Stopping Distance
	Time	Distance		
(mph)	(sec)	(ft)	(ft)	(ft)
30	2.5	110	48	158
40	2.5	147	89	236
50	2.5	183	144	327
60	2.5	220	214	434
70	2.5	257	297	554

*From "A Policy on Geometric Design of Rural Highways," AASHO, 1965. (18)

Reference to "Restricted Sight Distance" simply means that the actual sight distance for a six-inch object to be visible from a driver eye height of 3.75 feet is less than the minimum stopping distances listed in the table above. "Adequate Sight Distance" refers to a stopping distance meeting the criteria above and exceeding the values given in the table above.

signs or none at all. The alignment necessitated numerous steering and speed adjustments and was often deceptive. Sight distance restrictions (Table 3) were found on most alignment changes. R-O-W was restrictive, close in, and many times hazardous. The pavement condition was variable with edge deterioration occurring in some cases. The predominant bridge facility was restricted in width and had minimum delineation. Meeting opposing vehicles on the more narrow roadways required overt vehicle position adjustments to safely complete this driving maneuver. The predominant driver was unfamiliar (non-local). Break-point between one-lane and two-lane tracking occurred at a width of 14'.

Description -- State

The predominant paved State roadway was well-engineered with both horizontal and vertical alignment conducive to higher speed operation. The majority of pavement surfaces and edges seemed to be fairly well-maintained. A full complement of both warning and information signs was exhibited on almost all sections of road. Marking, where found, consisted of both centerline and no-passing zone stripes. Pavement markings were in fair condition, except on 18' roadway sections where markings were obliterated from two-lane tracking. All roadways had single metal post reflector type delineation on the sharper curves. Sight distance on the majority of the roadways was adequate (Table 3) even for the higher speeds, and was still adequate in those areas of rolling to mountainous topography. Almost all bridge structures were as wide as the approach roadway and had full advance delineation and hazard warning. R-O-W was characteristically wide and clear of obstructions and vegetation undergrowth. Some type of side slope design was attempted in most cases. There was no predominance of either familiar (local) or unfamiliar (non-local) drivers. Two-lane tracking occurred on roadways less than 20' wide, while separated two-lane tracking is characteristic of roadways 20' wide or wider.

Description -- County

A characteristic of paved County roadways was to induce speeds higher than was safe for the alignment. Unexpected changes in alignment were a commonplace and hazardous occurrence. A wide range of operating speeds, roadway widths, and traffic volumes were found on paved County roads. Almost all the roadways under study had no warning or information signs. Stop and yield signs were employed at most intersections of County roadways with other paved roadways. No stop control was used at any side road intersection. Only one paved County roadway was marked out of the entire study. Pavement surface was generally good with some edge raveling. Sight distance was adequate (Table 3) the majority of the time. R-O-W width and maintenance was fairly good. The predominant bridge structure and culvert were limited in width and unguarded. Delineation was scarce, and there was almost a total lack of advance warning. One-lane tracking was observed on roadways less than 14' wide; two-lane tracking on roadways 14' to 20' wide; and separated two'lane tracking on roadways 20' wide or wider. The predominant

Figure 1. Paved, Marked Federal Roadway

Figure 2. Unpaved, Unmarked Federal Roadway

Figure 3. Unpaved Federal Roadway

Figure 4. Paved Federal Roadway

Figure 5. Paved, Marked State Roadway

Figure 6. Unpaved State Roadway

Figure 7. Paved, Unmarked County Roadway

Figure 8. Paved, Unmarked County Roadway

Figure 9. Unpaved County Roadway

Figure 10. Unpaved County Roadway

driver on the paved County roadway was familiar (local). However, situations could and did occur where a County road traverses into a recreation area, and the character of the majority of drivers changes.

Typical Roadways (Unpaved)

Description -- Federal

These roadways exhibited very low speeds. The alignment on the majority of the facilities, both vertical and horizontal, was severe; yet, was adequate for low operating speeds. Roadway widths varied through a wide range; however, the majority were one-lane type operations. The better unpaved Federal roads were predominately for unfamiliar (non-local) drivers, while the lesser quality roads were for employee and various park service activities. The sight distance was restricted (Table 3) on almost all facilities, although it did not seem to present many problems at the low speeds. The R-O-W was restricted and close in. There were no warning or regulatory signs and few route markers or information signs. Some intersections had stop or yield signing. Very little curve or culvert delineation was employed. The bridge structures were predominately narrow or one-lane with little or no delineation. There were no operational problems on these structures at low speeds. The roadway character clearly defines the required safe operating responses. Roadways 14' wide or less exhibited strictly one-lane tracking, while on roadways wider than 14' there was found two-lane tracking.

Description -- State

Low to moderate speeds were found to be typical on all unpaved State roadways. Alignment was slightly severe at times, but otherwise, fairly well-engineered. The alignment would probably be hazardous at higher speeds. There was a wide range of roadway widths with the surface conditions of varying characteristics. The surface was the primary deterrant to higher speed operation. Sight distance was almost always adequate (Table 3) for lower operating speeds. R-O-W was mostly clear and wide; however, restricted sections did occur on either or both sides of the roads. There were few regulatory or information signs, although a full complement of warning signs was exhibited. All culverts were delineated, yet, there was no curve delineation. There was a diversification of bridge structures. The majority had hazard warning signs and delineation. Opposing vehicular maneuvers are performed without problems. Stop signing and advance warning was found at intersections with roadways of higher character. Some stop or yield signs were employed at intersecting side roads. No predominance of familiar (local) or unfamiliar (non-local) drivers was found. Two-lane tracking occurs on roadways less than 20' wide; while separated two-lane tracking is strictly characteristic of roadways 20' wide or wider. There were isolated instances of one-lane tracking caused by very low volumes or poor roadway surface condition.

Description -- County

The typical unpaved County road exhibited low to moderate normal operating speeds. The alignment was non-engineered with sudden, unexpected changes. Roadway widths were predominately one-lane in width. There was a wide range of traffic volumes. There were no warning signs and very few information signs. Stop or yield signs were used at intersections with paved roadways. Side roads intersecting the unpaved County road had no stop control. Some roadways were well-maintained, while others were fairly rough with holes and low-water crossings. R-O-W was limited and restricted by vegetation which resulted in restricted sight distance (Table 3) on many curves. Bridge structures and culverts were predominantly one-lane and unguarded. Delineation was almost non-existent. One-lane tracking was observed on roadways less than 14' wide, and two-lane tracking on roadways 14' wide to 20' wide. The predominant driver on the unpaved County roadway was familiar (local).

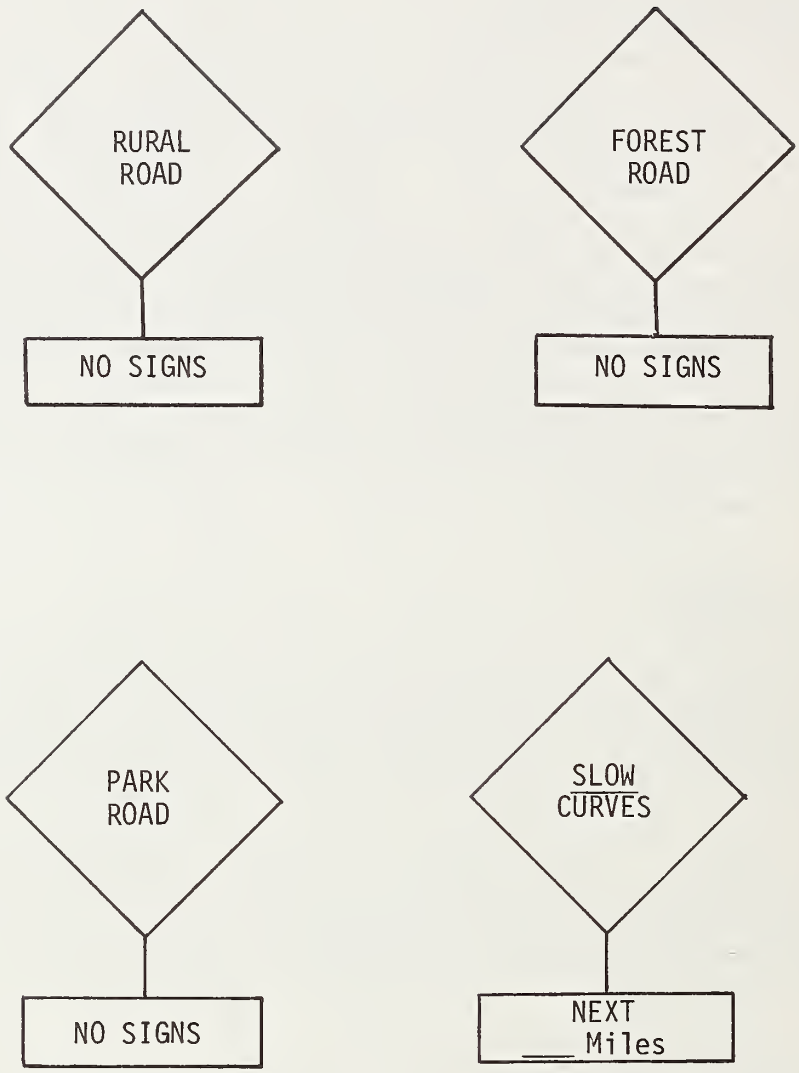
GENERAL FINDINGS

By employing the same methodology as previously mentioned, i.e., a study team analysis, recommendations and justifications for practice in signing and marking of low volume rural roads were proposed. Throughout these recommendations, reference is made to "normal operating speed." This term refers to the speed at or near which the majority of vehicles are traveling. More technically, this term relates to the ten mile per hour pace speed. It was indicated throughout the field observations that 40 mph constituted a breakpoint between a condition where supplemental driver information was needed and a condition where the roadway itself provided adequate information. Subsequent analyses supported this proposition.

Low Volume Rural Roads (Paved)

General Low Volume Warning Signs

Recommendation -- If the normal operating speed on the paved roadway is less than 40 mph, regardless of whether speed is being influenced by roadway geometric, surface, environmental, or sight distance (Table 3) restrictions, a general warning sign should be placed at the beginning of an extended section of roadway and beyond the intersection of all paved roadways in lieu of the standard MUTCD signing practice. Alternative general warning signs for particular situations are as follows:



The sign should be 24" x 24" with black lettering on a yellow background.

Justification -- This type of signing conveys a message to the driver concerning the physical characteristics that will be encountered on the roadway ahead and the necessary caution to be exercised. These signs, along with the operational constraints imposed by the roadway itself, satisfy to an adequate degree the safety measures required on low volume, low speed roads. The reduced sign size, 24" x 24", also provides the necessary legibility at lower speeds. This is very desirable from an economic viewpoint.

Route Confirmation, Destination, and Information

Recommendation -- Even though these types of signs are used to convey guidance information rather than safety advisement, several recommendations are included in this study. It is suggested that a standard route turn assembly, route destination sign, information, scenic area, or recreational signs, whichever serves as the most effective and appropriate navigational aid, be placed on all paved roadways in advance of any interesecting roadway leading to geographical locations (park, lake, etc.) where the activities generate prodominantly unfamiliar (non-local) drivers. At T-intersections, these signs should be placed in the center of the "T" to better define the intersection for those drivers on the non-through approach. If at all possible, the use of a single sign at each intersection is recommended, or possibly two signs could be mounted on one pole. The placement of these signs is not dependent on terrain, environmental conditions, or geometric alignment. If the normal operating speed is 40 mph or greater, use the standard MUTCD size signs. If the normal operating speed is less than 40 mph, use a 12" x 12" MUTCD design route confirmation sign.

Justification -- The purpose of this signing is to convey guidance information to the unfamiliar (non-local) driver in a given situation utilizing the most appropriate sign. This purpose must be economically balanced by using as few signs as possible which provide the necessary information. The relationship of these type signs to speed is governed by legibility. The message is conveyed by word or number recognition, not symbolically. Minimum information signing is also very desirable aesthetically as is the use of the smaller signs where lower operating speeds provide adequate legibility. The standard MUTCD signing in these areas is required for legibility for speeds in the higher range.

Speed Limit Sign

Recommendation -- Speed limit signs (standard MUTCD) shall be placed on paved roadways under the following guidelines:

If the normal operating speed (or 85th percentile) is 50 mph or greater, placement shall be at all points where dissimilar speed limits or speed reduction areas terminate or begin and beyond all intersections with other paved roadways. Do not place speed limit signs on any roadways with normal operating speeds less than 50 mph as terrain, sight distance, or geometric conditions will establish the safe speed and the roadway itself will serve as reinforcement.

Justification -- If the normal operating speed on a facility is greater than 50 mph, it is very likely that a proportionate number of speeds above the legal maximum speed limit will occur and some type of regulatory signing reinforcement is required for safety. The recommendation for speeds above 50 mph is neither aesthetically or economically favorable, while the recommendation for speeds below 50 mph is most desirable from an economic and aesthetic viewpoint.

Pavement Markings (Centerline and No Passing)

Recommendation -- Do not mark any roadways less than 20' wide. Do not mark any roadways of width 20' or greater if the normal operating speed is 40 mph or less. Mark all roadways which have a pavement width of 20' or greater, normal operating speeds greater than 40 mph, and sight distance restrictions (Table 3) due to type of terrain, environmental conditions, or geometric alignment. Two marking alternatives are as follows:

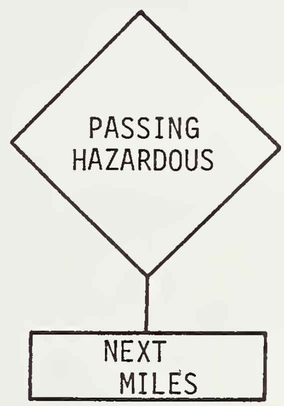
- Use the standard MUTCD centerline and no passing marking practice.
- Use a centerline consisting of two solid, yellow, 1.5 inch wide lines separated by a 1.0-inch gap between the lines.

Justification -- From an aesthetic point of view, elimination of pavement marking is by far the more desirable. Pavement marking introduces a formal pattern to the surrounding informal environment. Economically, it is obviously more desirable not to have pavement markings. Markings on roadways less than 20' wide serve no purpose as the tracking characteristics of drivers on these roadways as discussed in the preceding field descriptions, will cause the markings to be obliterated, and the desired effect is negated. Probably the next most economical alternative would be the two 1.5-inch strips. The labor cost between this and the solid 4-inch striping method would be approximately the same with the difference coming in paint saving. The most costly pavement marking would be the standard MUTCD practice.

With respect to safety, adequate separation of opposing traffic on roadways less than 20' wide cannot be attained through the use of pavement markings. This is especially true when roadway conditions are poor or unsafe immediately adjacent to the pavement edge. Wider, low-speed roadways are also safe without marking. This can be attributed to three factors: (1) low speed allows adequate response them, (2) the wider pavement provides the space for vehicular movement through an avoidance maneuver, and (3) characteristic driver behavior is to make a right lateral vehicle shift when sight distance is restricted (Table 3). Roadways 20' or greater are more suited operationally to effectively separate traffic with pavement markings, which becomes a necessity when higher speeds and restrictive sight distances prevail. The double 1.5-inch stripes are proposed as a unique type of practice which would be dual purpose in defining both centerline and continuous no passing on roadways where passing is hazardous throughout.

Passing Advisement Signing

Recommendation -- This type of sign should be used to designate an extended length of roadway where passing may be hazardous or should be undertaken with caution due to roadway width, surface, or sight distance restrictions (Table 3) caused by terrain conditions or geometric alignment. This sign should be employed in a cautionary-regulatory type capacity, whichever is needed, on all unmarked roadways as designated under "Pavement Markings." They could be used in a reinforcing manner on marked roadways as designated under "Pavement Markings." Do not place a passing advisement sign on any paved roadway less than 20' wide. The suggested sign size would be 30" x 30". The design should be diamond-shaped with black on yellow. This sign should be erected at the beginning of a section of roadway necessitating passing advisement and/or warning and beyond the intersection of all paved roadways.



Justification -- Roadways less than 20' wide are not suited to passing maneuvers from a safety standpoint under any conditions, and no additional signing is necessary to convey this to the driver on roadways less than 20' wide. This type of sign is used to provide the unfamiliar driver with information, independently or in conjunction with markings, about the character of the roadway and the necessary operational measures to be taken for safety. One sign describes to the driver the nature of the passing maneuver on the facility for a given distance ahead. On a marked roadway, this sign reinforces passing restrictions. Aesthetically, the sign itself is undesirable; however, it may be as desirable as marking. Economically speaking, a single sign is very much cheaper than striping several miles. The size of this sign should be 30" x 30".

Railroad Crossing Sign

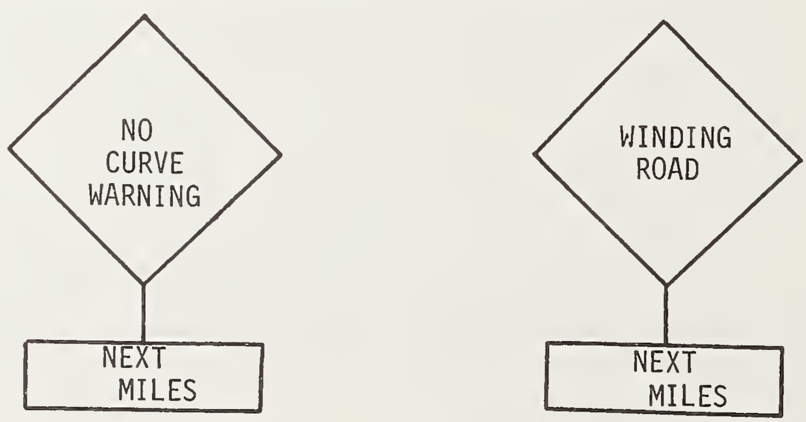
Recommendation -- At all operating speeds, use the standard MUTCD RR crossing sign, reduced to 36" x 7", in advance of any railroad crossing. A railroad advance warning sign, standard MUTCD, reduced to 24" diameter, should be erected in the advance approach to a RR crossing where sight distance to the crossing is restricted (Table 3) due to terrain, environmental conditions, or geometric alignment.

Justification -- A railroad crossing consitutes a hazard at any speed and requires separate, distinct warning and definition. The RR crossing sign and advance warning are basically symbolic and readily recognizable. Therefore, the standard MUTCD size sign may be reduced. Neither of these signs is aesthetically pleasing; however, economically, as well as aesthetically, the smaller the sign, if legible, the better.

Curve Warning

Recommendation -- If the predominant driver on the paved roadway is unfamiliar (non-local) and/or normal operating speed is 40 mph or greater, use the standard design (MUTCD) for curve, reverse curve, or winding curve signs where roadway geometric, surface, environmental, or sight distance restrictions (Table 3) limit the safe operating speed within the curve to 10 mph or more below the approach operating speed. The size of the sign should be 24" to 24" which is smaller than the MUTCD standard. Advisory speed plates should be used in conjunction with curve warning when the curve speed reduction is 15 mph or more.

If the predominant driver on the paved roadway is familiar (local) and/or normal operating speed is less than 40 mph, regardless of whether speed is being influenced by roadway geometric, surface, environmental, or sight distance restrictions (Table 3) a general curve warning sign should be placed at the beginning of an extended section of roadway containing numerous sharp curves and beyond the intersection of all paved roadways. General curve warning signs are as follows:



The sign size should be 24" x 24" with black lettering on yellow background.

Justification -- With higher speeds and/or unfamiliar (non-local) drivers, curve warnings of the former type are necessary to alert the driver that he or she is approaching a situation which requires adjusted vehicular position or speed responses to maintain vehicular safety. The standard curve symbol signs (MUTCD), even reduced to 24" x 24", are symbolic signs and, therefore, should adequately convey the needed message. Speed advisory plates should be used to indicate the severity of the curve, and thus the degree of driver response required. The reduction in sign size would be economically desirable and more aesthetically pleasing.

The latter type signing technique conveys a message to the driver to be alert and cautious on all curves. This concept is adequate from a safety standpoint for familiar (local) drivers and/or normal operating speeds less than 40 mph. The reduced sign size, 24" x 24", provides the legibility necessary to respond and negotiate the correct, safe vehicular maneuver. This is vary desirable from an economic viewpoint.

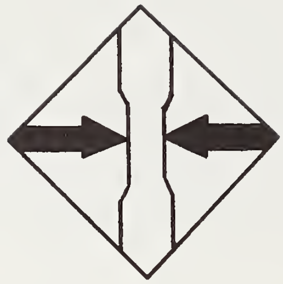
Stop Ahead

Recommendation -- If the normal operating speed is 40 mph or greater, place the standard MUTCD "Stop Ahead" sign, reduced to 24" x 24", in advance of any stop-controlled intersection where sight distance (Table 3) to the intersection is restricted due to terrain, environmental conditions, or geometric alignment. "Stop Ahead" signs are not necessary if the normal operating speed on the roadway is less than 40 mph.

Justification -- The placement of this type sign cannot be deemed aesthetically pleasing; however, the smaller, if legible, the size of the sign, the more desirable. Reduction in sign size will reduce the cost of signing. This sign is needed for safety with higher normal operating speeds to provide adequate stopping sight distance (Table 3) in situations of limited intersection visibility. The "Stop Ahead" message is clear, concise, and readily discernable. Therefore, a reduction in size of sign should still provide adequate legibility. No advance warning is needed at speeds below 40 mph because the lower speeds allow adequate response time.

Narrow Bridge Sign

Recommendation -- If the normal operating speed is 40 mph or greater, place the standard MUTCD narrow bridge sign, only reduced to 24" x 24", in advance of any bridge having a roadway clearance less than the width of the approach pavement and where sight distance (Table 3) to the bridge is restricted due to terrain, environmental conditions, or geometric alignment. A possible alternative symbolic type sign, also 24" x 24", is as follows:



This sign would also be 24" x 24" with black lettering on yellow background. Do not use narrow bridge signs if the normal operating speed on the roadway is less than 40 mph.

Justification -- The placement of this type sign is not in aesthetic harmony with the natural surroundings; yet, the smaller the sign, the more aesthetically and economically desirable. The existing "Narrow Bridge" sign is easily recognizable and interpretable; therefore, a reduction in size of sign should still provide adequate message transfer. The alternative symbol sign is yet to be tested. These types of signs are needed for safety with higher normal operating speeds to provide the necessary distance and time for vehicular maneuver adjustments in proceeding across a narrow bridge. No advance warning is required at lower speeds because the needed response time is already provided for in almost any situation.

Special Signs

Recommendation -- Use of special signs (deer crossing, falling rocks, etc.), designated by either the park or forest service, should be considered wherever specific local conditions warrant a need for warning.

Justification -- Situations necessitating the need for these type of signs more likely occur in a rural, mountainous, or forest environment. Placement of these signs is dependent on not only safety, but aesthetics and economy as well. Elimination of signs is the most desirable aesthetically, yet the size of color of the forest and park service signs are more conducive to blending with the natural environment than the standard MUTCD. The cost, relative to size, should also be less.

Delineation

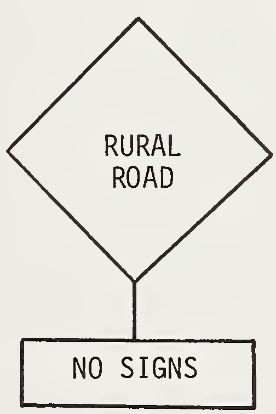
Recommendation -- Single white post-mounted reflectors should be used on horizontal curves where sight distance, due to terrain, environmental conditions, or alignment, does not provide adequate curves visibility in a nighttime approach under normal driving speeds. These delineators should be located on the outside of the curve in question according to standard MUTCD placement requirements. They should also be placed to define curves where conditions immediately off the pavement edge are hazardous. Single yellow post-mounted reflectors should be located adjacent to all culverts in both directions and multiple delineators should be erected in advance of any bridge structure. For the express purpose of nighttime definition, the yellow reflectors should be used as recommended regardless of speed, terrain, environmental conditions, geometric alignment, or surface condition.

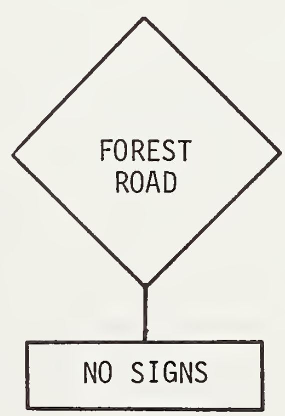
Justification -- The purpose of delineation is to provide added nighttime alignment definition to those curves not clearly visible in approach or to those curves that are potentially hazardous due to terrain or higher operating speed at night. Culverts and bridge structures are hazards which always need nighttime markings for driver safety on whatever class of roadway. Delineation is costly, but may be justified when compared to hazard signing it may be desirable over other alternatives to accomplish a similar measure of safety.

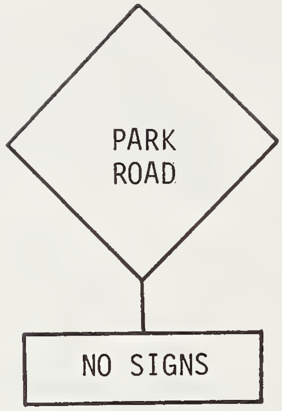
Low Volume Rural Roads (Unpaved)

General Low Volume Warning Signs

Recommendation -- If the normal operating speed on the unpaved roadway is less than 40 mph, regardless of whether speed is being influenced by roadway geometric, surface, environmental, or sight distance (Table 3) restrictions, a general warning sign should be placed at the beginning of an extended section of roadway and beyond intersections with paved roadways in lieu of the standard MUTCD signing practice. Alternative general warning signs for particular situations are as follows:







This sign should be 24" x 24" black lettering on a yellow background.

Justification -- This type of signing conveys a message to the driver concerning the physical characteristics that will be encountered on the roadway ahead and the necessary caution to be exercised. These signs, along with the operational constraints imposed by the roadway itself, satisfy to an adequate degree the safety measures required on low volume, low speed roads. The reduced sign size, 24" x 24", also provides the necessary legibility at lower speeds. The reduced sign size and number is very desirable from an economic viewpoint.

Route Confirmation, Destination, and Information

Recommendation -- Use the standard MUTCD route turn assembly sign reduced to 12" x 12" on all unpaved roadways in advance of any intersecting roadway. This, or any other appropriate type of route confirmation, route destination, recreation, scenic area, or information sign, whichever is most effective in conveying guidance information, should be placed on unpaved roadways in advance of any other intersecting roadway leading to geographic locations where the activities generate predominantly unfamiliar (non-local) drivers. The placement of navigational signs does not depend upon terrain, sight distance, or geometric alignment. Frequency and placement of these type signs may very with locality, multitude of points of interest, or desired extent of the message to be displayed. A concerted effort should be exercised in the selection of an appropriate sign for a given situation to limit sign placement to one sign per intersection approach. If two signs are needed, they could possibly be mounted on one pole.

Justification -- The purpose of this signing is to convey guidance information to unfamiliar (non-local) drivers utilizing signs best suited to individual situations. The smaller route confirmation sign is economically desirable. The erection of these signs is not aesthetically pleasing. However, fewer signs are more favorable aesthetically than the existing MUTCD practice. The characteristically low operating speeds on these roadways will permit the reduction in sign size while maintaining adequate legibility.

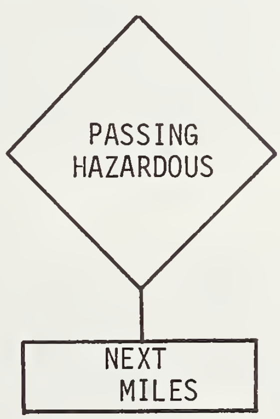
Speed Limit

Recommendation -- Do not place speed limit signs on any unpaved roadways unless required by law.

Justification -- The characteristics of unpaved roadways establish and regulate the required safe operating speed. Terrain, surface condition, geometric alignment, and sight distance combine as operational inputs to dictate the safe speed of the facility. This recommendation not only produces the ultimate aesthetic effect, but is also economically desirable.

Passing Advisement Signing

Recommendation -- Do not place a passing advisement sign on any unpaved roadway less than 20' wide. A passing advisement sign should be placed on unpaved roadways with width 20' or wider to designate an extended length of roadway where passing would be hazardous or should be undertaken with caution due to roadway width, surface condition, sight distance restrictions (Table 3) attributable to terrain, and/or geometric alignment. The suggested sign size is 30" x 30" for roadways with normal operating speeds 40 mph or greater, and 24" x 24" for roadways with normal operating speeds less than 40 mph. The design should be diamond-shaped with black on yellow. This sign should be erected at the beginning of a section of roadway necessitating passing advisement and/or warning and beyond intersections with paved roadways.



Justification -- Roadways less than 20' wide are not conducive to passing in any situation and no signing is necessary to indicate this to the driver. On roadways 20' wide or wider, this type of sign is used to provide the driver with information about the character of the roadway and the necessary operational measures to be taken for driving safety. In this case, one sign describes to the driver the measure of safety needed in the passing maneuver on the facility for a given distance ahead. Aesthetically, the sign itself is undesirable, but this must be measured against the necessary safety requirements. Economically speaking, a single sign is relatively inexpensive if it influences the driver to maintain a greater degree of safety for an extended length of roadway. The smaller sign, 24" x 24", is justified by adequate legibility at reduced speeds.

Railroad Crossing Sign

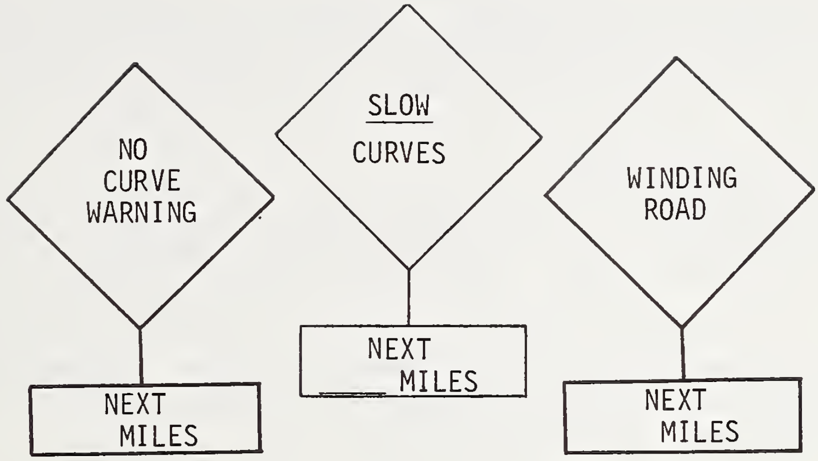
Recommendation -- Use the standard MUTCD RR crossing sign, reduced to 36" x 7", in advance of any railroad crossing regardless of normal operating speed, sight distance, terrain, environmental conditions, or geometric alignment. Do not use railroad advance warning signs in any situation on unpaved roadways.

Justification -- A railroad crossing constitutes a unique hazard at any operating speed and always requires separate, distinct warning and definition. The RR crossing sign, even in reduced size, is basically symbolic, and therefore, is readily recognizable. No advance warning is justified as the lower normal operating speeds allow more than adequate response time. The reduction in RR crossing signs and deletion of the advance warning sign is both economically and aesthetically desirable.

Curve Warning

Recommendation - If the normal operating speed on the unpaved roadway is 40 mph or greater, use the standard design (MUTCD) for curve, reverse curve, or winding curve signs where roadway geometric, surface, environmental, or sight distance restrictions (Table 3) limit the operating speed. The size of the sign should be reduced to 24" x 24" which is smaller than the MUTCD standard. Advisory speed plates should be used in conjunction with curve warning when the curve speed reduction is 15 mph or more.

If the normal operating speed on the unpaved roadway is less than 40 mph, regardless of whether speed is being influenced by roadway geometric, surface, environmental, or sight distance restrictions (Table 3), a general curve warning sign should be placed at the beginning of an extended section of roadway containing numerous sharp curves and beyond intersections with paved roadways. General curve warning signs are as follows:



This sign color should be black lettering on yellow background.

Justification -- With higher speeds, 40 mph or greater, curve warnings of the former type are necessary to alert the driver that he or she is approaching a situation which requires vehicular position or speed responses to maintain safety. The standard curve symbol signs (MUTCD), reduced to 24" x 24", adequately convey the needed message. Speed advisory plates should be used to indicate the severity of the curve and, thus, the degree of driver response required. The reduction in sign size would be economically desirable and more aesthetically pleasing.

The latter type signing technique conveys a message to the driver to be alert and cautious on all curves. This concept is adequate from a safety standpoint for familiar drivers and/or normal operating speeds less than 40 mph. The reduced sign size, 24" x 24", provides the legibility necessary to respond and negotiate the correct, safe maneuver. This reduction is sign size and number is very desirable from an economic viewpoint.

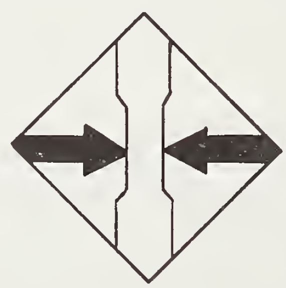
Stop Ahead

Recommendation -- If the normal operating speed is 40 mph or greater, place the standard MUTCD "Stop Ahead" sign, reduced to 24" x 24", in advance of any stop-controlled intersection where sight distance (Table 3) to the intersection is restricted due to terrain, environmental conditions, or geometric alignment. No "Stop Ahead" sign is necessary if the normal operating speed on the roadway is less than 40 mph.

Justification -- The placement of this type sign cannot be deemed aesthetically pleasing; however, the smaller, if legible, the size of the sign, the more desirable. Reduction in sign size will reduce the cost of signing. This sign is needed at higher normal operating speeds to provide adequate stopping sight distances (Table 3) in situations of limited intersection visibility. Therefore, a reduction in sign size should still provide adequate legibility. No advance warning is needed at speeds below 40 mph because the lower speeds allow adequate response time.

Narrow Bridge Sign

Recommendation -- If the normal operating speed is 40 mph or greater, place the standard MUTCD "Narrow Bridge" sign, reduced to 24" x 24", in advance of any bridge structure having a roadway clearance less than the width of the approach pavement. This sign is especially important where sight distance (Table 3) to the bridge is restricted due to terrain, environmental conditions, or geometric alignment. A possible alternative symbolic type sign is as follows:



This sign would also be 24" x 24" with black lettering on a yellow background. Do not use narrow bridge signs if the normal operating speed on the roadway is less than 40 mph.

Justification -- The placement of this type sign is not in aesthetic harmony with the natural surroundings; yet, the smaller the sign, the more aesthetically and economically desirable. The existing "Narrow Bridge" sign is easily recognizable and interpretable; therefore, a reduction in size of sign should still provide adequate message transmission. The alternative symbol sign is yet to be tested except by questionnaire survey (Appendix A). These types of signs are needed at higher normal operating speeds to provide the necessary time for vehicular position adjustments in proceeding across a narrow bridge. No advance warning is required at lower speeds because adequate response time is available.

Special Signs

Recommendation -- Use of special signs (deer crossing, cattle crossing, falling rocks, farm machinery, etc.) should be considered where specific local conditions warrant, regardless of normal operating speeds. These signs should be standard MUTCD designs, reduced to 24" x 24".

Justification -- Situations necessitating the need for these types of signs more likely occur in a rural, mountainous, or forest environment. The use of this type sign is not related to the operational features of roadway; i.e., external factors warrant the need for a specific warning sign. Placement of these signs is dependent on not only safety, but aesthetics and economy as well. As this type of sign is symbolic, sign size may be reduced while maintaining adequate legibility. Elimination of signs is an aesthetic improvement over the standard MUTCD. The cost, relative to size, should be less.

Delineation

Recommendation -- Single white post-mounted reflectors should be used on horizontal curves where sight distance, due to terrain, environmental conditions, or alignment, does not provide adequate curve visibility in a nighttime approach under normal driving speeds. These delineators should be located on the outside of the curve according to standard MUTCD placement requirements. They should also be placed to define curves where conditions immediately off the pavement edge are hazardous. Single yellow post-mounted reflectors should be erected in advance of any bridge structure. For the express purpose of nighttime definition, the yellow reflectors should be used as recommended regardless of speed, terrain, environmental conditions, geometric alignment, or surface condition.

Justification - The purpose of delineation is to provide added nighttime alignment definition to those curves not clearly visible in approach or to those curves that are potentially hazardous due to terrain or higher operating speed at night. Culverts and bridge structures are hazards which always need nighttime marking for driver safety. Delineation is expensive, but may be justified when compared to hazard signing or warning. Delineation has no aesthetic quality, although it may be desirable over other alternatives needed to accomplish a similar measure of safety.

DETAILED ANALYSIS AND DESIGN VALIDATION

The proposed methods of signing and marking of low volume rural roads, as outlined in the previous section, were arrived at by keeping upmost in mind the balance between safety, economy, and aesthetics. The recommendations presented previously were based primarily upon determinations resulting from study of the visual and auditory data recorded in the field. Further study and analysis was undertaken with emphasis placed again on safety, economy, and aesthetics. Special attention was placed on intersection control, horizontal curvature, and the passing maneuver. A driver comprehension survey was also taken through the administration of a questionnaire to the public. Driver recognition and understanding is an essential element for a validation of any modification of signing and marking practice.

COST OF ROADSIDE SIGNING AND MARKING

Introduction

This section examines some cost aspects of installation and maintenance of highway signs along low volume rural roads. The information presented in this section should not be interpreted as a cost study. Instead, the data in this section should be viewed only as approximations. There is a wide range of variables which affect sign costs, installation, and maintenance. For example, weather, terrains, sign material, vandalism, usage rates, etc. are functional related to each of the categories.

The information presented in this section was obtained from several sources. The sign costs data were obtained from the Federal Prison Industries, Inc., in Atlanta, Georgia. Data regarding installation and maintenance was furnished by various county road engineers throughout the country.

Sign Costs

Costs data presented in this section were obtained entirely from Federal Prison Industries, Inc. Reports No. 184 and 191. This is the primary source of signing devices for the U.S. Forest Service. In addition to roadside signs specified in the <u>Manual on Uniform Traffic Control Devices</u>, Report No. 184 presents rustic type signs familiar to drivers visiting National Forest facilities. Sign costs presented are for aluminum reflective purchased in quantities of 50 or more per specified size. Acquisition costs will increase for purchase orders of less than 50 signs.

Table 4. Highway sign costs: Aluminum reflective in quantity of 50 or more

Size of Sign	Price
9" x 24"	$ 5.30
12" x 18"	5.20
12" x 36"	9.00
13" x 13"	5.20
18" x 18"	7.15
18" x 24"	9.00
18" x 30"	10.80
18" x 48"	16.90
24" x 24"	11.95
24" x 30"	14.40
24" x 36"	16.90
24" x 48"	22.10
30" x 30"	17.55
30" x 48"	27.00
36" x 36"	24.55
48" x 48"	42.75
30" Triangle	9.90
36" Triangle	14.00
30" Circle	18.40

Source: Signs and Related Items Price List, United States Department of Justice, Federal Prison Industries, Inc. Washington, D.C., 20534. Report No. 191. (21)

Table 5. Average reported total costs of highway sign and installation by sign type and size

Sign	Size (in inches)	Average Reported Total Costs
Stop	30 x 30	$47.52
Stop	24 x 24	40.00*
Road Closed	48 x 30	38.50
Weight Limit 10 Tons	24 x 30	34.91
Turn Sign	30 x 30	35.22
Advisory Speed Plate	18 x 18	29.16
Curve Sign	30 x 30	35.22
Reverse Turn	30 x 30	35.22
Reverse Curve	30 x 30	35.22
Winding Road	30 x 30	35.22
Large Arrow	48 x 24	44.45
Cross Road	30 x 30	35.22
Stop Ahead	30 x 30	35.22
Yield Ahead	30 x 30	37.29
Bump	30 x 30	35.22
Dip	30 x 30	37.29
Pavement Ends	30 x 30	37.29
Soft Shoulders	30 x 30	35.22
Railroad Crossing	36 Diameter	48.24
Dead End	30 x 30	25.22
Directional Arrow	21 x 15	26.00*
Road Narrows	36 x 36	49.58
One Lane Bridge	36 x 36	49.58
Bicycle Crossing	30 x 30	29.40*
Low Clearance	36 x 36	59.82
Low Clearance	24 x 18	34.32*
County Route Marker	24 x 24	21.60
Speed Limit	24 x 30	34.01
Road Closed 10 Miles Ahead Local Traffic Only	60 x 30	47.04
Narrow Bridge	30 x 30	38.24
Yield	48 x 48 x 48	43.61*
Yield	36 x 36 x 36	32.20*
Yield (Engineer Grade Scotchlite)	36 x 36 x 36	37.00*
Yield (High Intensity Grade Scotchlite)	36 x 36 x 36	45.00*

*Indicates only one estimate provided.
Source: Average computed from forms completed and returned by County Engineer.

Highway sign cost by size is presented in Table 4. These prices are quoted by the Federal Prison Industries, Inc. These prices are FOB factory and are for all standard two-color (one color on one background color) signs as shown in the MUTCD. Sign costs increase as a function of size. Unit costs computed on a surface area basis, however, decline with increases in size. If acquisition costs are the cruicial element the smallest acceptable sign should be selected for installation.

Installation Costs

A questionnaire concerning installation costs of roadside signs on low volume rural roads was sent to selected county engineers. Although no letter was returned because it was undeliverable, the response rate of the questionnaire was less than satisfactory. The poor response rate precluded any attempt to develop an in-depth analysis of either installation or maintenance costs. Table 5 presents the average reported installation costs by size of sign. The cost estimates presented in the table include both the price of the sign and associated costs for installation (labor, machinery, posts, and etc.). Generally, the total costs exhibit the same characteristics as found in the price list - costs increasing with sign size. There was a considerable range of cost estimates furnished by the responding counties.

Although the questionnaire asked only for the cost of sign installation, the responding counties furnished total costs of sign and installation. While the inclusion of sign cost is acceptable if they are comparable, the wide range of total costs raises questions concerning their comparability. Sign costs and installation costs should be computed separately.

The costs associated with fabrication of a highway sign may vary considerably between counties. Also, there may be a significant difference between the counties and Prison Industries, Inc. Therefore, estimates of installation costs developed in this section may not be entirely reflective of a particular agency cost.

Table 6 presents the total average highway sign costs by size catagories. These cost estimates were computed from the information provided by the responding counties and may not be entirely representative. These estimates do however, indicate that total costs are increasing with size while average costs per square foot are declining. The larger the sign the higher the costs of the sign and installation charges. Supports, equipment, machinery, and labor will be more expensive for larger signs. However, the very large highway signs are seldom located on low volume rural roads.

Using the information contained in Table 4 relative to the sign price and that in Table 6 on reported total costs, sign installation estimates were developed, Table 7. On a square foot basis the smaller

Table 6. Average reported total costs for highway signs by size catagory

Size Catagory (in inches)	Square Feet	Reported Average Total Costs	Average Costs Per Square Foot
30 x 30	6.25	$36.20	$ 5.792
24 x 24	4	30.80	7.700
18 x 18	2.25	29.16*	12.960
36 x 36	9	52.99	5.888
48 x 30	10	38.50*	3.850
48 x 24	8	44.45*	5.556
24 x 30	5	34.46	6.892
60 x 30	12.5	47.04*	3.763
21 x 15	2.1875	26.00*	11.886
24 x 18	3	34.32	11.440

*Indicates only one sign type in this size category.

Table 7. Average estimated installation costs of highway signs by size catagory

Size Catagory (in inches)	Square Feet	Installation Costs (per square foot)	Total Installation Costs
30 x 30	6.25	$2.982	$18.64
24 x 24	4.0	4.71	18.84
18 x 18	2.25	9.78	22.01
36 x 36	9.0	2.825	25.43
48 x 30	10.0	1.15	11.50
48 x 24	8.0	2.856	22.85
24 x 30	5.0	4.012	20.06
60 x 30*	12.5	1.143	14.28
21 x 15*	2.1875	8.686	19.00
24 x 18	3.0	8.44	25.32

*No price shown in Report No. 191, Estimated for 60 x 30, $32.75; 21 x 15, $7.00.

signs have a higher installation cost. Support costs and placement (machinery, equipment, and labor) are apparently the same for the various sign sizes for which information was furnished. When evlauated on a total installation basis the estimated costs tend to be in a range of $18.50 to $25.50 for the various sign sizes. However, there were two estimates outside this range. Both were the larger reported sign sizes.

The installation cost estimates developed can be used as guidelines in evaluation of various alternative size signs. Since these estimates were developed from limited cost information, they may be either over or understated. This is especially true if the cost of the sign to the county (either purchased or fabricated by the county) is significantly different than the price list of the Federal Prisons Industries, Inc.

Maintenance Costs

In addition to installation there are maintenance costs involved in highway signing. The questionnaire sent to the counties asked for estimates of maintenance costs by type of sign. The response was even less satisfactory than the response to installation costs.

Of the four counties responding only three furnished usable data. The fourth county provided information on the number of signs which had to be replaced and reported total annual sign replacement costs to the county. Those counties providing information on the sign maintenance costs indicated that the estimates were developed on the basis of expected sign life - a depreciation schedule. While data on maintenance costs experience would be preferred, the data provided does furnish guidelines on this aspect of signing.

Three estimates of sign life were furnished by the counties, 10, 8, and 6 years. Maintenance costs estimates were developed on the basis of 10%, 12.5%, and 16% of total sign costs. Table 8 presents the estimated sign maintenance costs by sign size. Although these maintenance cost estimates appear relatively low, it should be pointed out that total maintenance costs for the responding counties may be large and are related to miles of county maintained roads and total sign needs. One county which provided nonusable data indicated that total signs and marking expenditures for 1974, including purchase, erection and maintenance was almost $145.00 per mile. This included both low volume and other county roads.

Delineator and Marking Costs

Counties were asked to furnish cost data on the installation and maintenance of delineators and roadway striping. Only one respondent provided cost data on the installation of delineators. Three counties

Table 8. Estimates of sign maintenance costs

Sign Size	Costs Base*	Maintenance Cost Base On: 10% of Total Costs	12.5% of Total Costs	16% of Total Costs
30 x 30	$36.20	3.62	4.53	5.79
24 x 24	30.80	3.08	3.85	4.93
18 x 18	29.16	2.92	3.65	4.67
36 x 36	52.99	5.30	6.62	8.48
48 x 30	38.50	2.85	4.81	6.16
48 x 24	44.45	4.45	5.56	7.11
24 x 30	34.46	3.45	4.31	5.51
60 x 30	47.04	4.70	5.88	7.53
21 x 15	26.00	2.60	3.25	4.16
24 x 18	34.32	3.43	4.29	5.49

*See Table 6.

provided cost data on highway striping. However, one county only provided an average cost per mile regardless of the marking applied.

The cost estimates for striping are presented below. Although these estimates are developed from limited data, one county indicated that the prices were for the 1974 striping contract.

• Broken white line (#1, Sec. 3A-7)*	$ 49.87 per mile
• Broken yellow line (#2, Sec. 3A-7)	49.87 per mile
• Solid white line (#3, Sec. 3A-7)	91.87 per mile
• Broken yellow line w/solid yellow line (#5, Sec. 3A-7)	141.75 per mile
• Solid yellow line (#9, Sec. 3A-7)	88.62 per mile

*See Sec. 3A-7 MUTCD

• Average 1974 Costs (one county)	60.10 per mile

The estimates furnished by the counties by specific marking exhibited a high degree of similarily. In only one category were the cost estimates different.

The responding counties also provided estimates on the life of the highway markings and their schedule of re-striping. One county indicated that all striping was renewed each year. Another county responded that re-striping occurred every three years.

Summary

The data presented in this section on installation costs of signs and markings should not be viewed and interpreted as a cost study. The estimates presented in this section were developed from limited responses. However, the data presented do provide some cost guidelines for selecting roadside signs on low volume rural roads.

The installation cost estimates indicate that within the range of sign sizes examined there were no economics. Since very large highway signs are seldom, if ever, used on low volume rural roads, the installation costs should not be expected to exhibit an increasing function. The support, mounting, equipment, machinery, and labor required to install a 30" x 30" "STOP" sign should not be significantly greater than that of a 24"x 24" "NO TRUCKS" sign.

The maintenance cost of roadside signs is primarily one of sign replacement. One county indicated that 85 percent of maintenance was replacing signs damaged by vandalism. This county reported spending over $8,800 to replace signs in 1974. Maintenance on highway markings is basically a re-striping effort performed on a prearranged schedule.

In conclusion, it seems the only economy to be achieved with respect to roadside signs is through a general reduction in number installed. This produces an initial savings in material and installation costs over the present costs. Also, if vandalism cannot be decreased, this reduces maintenance costs by having fewer signs along the roadway requiring replacement. With respect to roadway markings, the suggestion is not to alter the maintenance schedule of re-striping operation. However, the use of the slightly smaller width double yellow lines would give a 25% reduction in paint costs without increasing labor costs. This practice would only deviate slightly from present practice and hopefully exhibit the desired meaning to the driving public.

AESTHETICS

Introduction

Historically, signing and marking on low volume rural roads, whether they be under county, state, or federal jurisdiction, relied upon MUTCD (Manual on Uniform Traffic Control Devices) for warrants and guidelines for the placement of motorist information and driving aids. On these roads which are generally of low design standards, the engineers and maintenance people have sometimes felt that it was necessary to sign and mark this class of highway to the same standard as state primary or secondary roads which carry heavy traffic in order to fulfill the recommendations of MUTCD. Since the growth of environmental groups and economic-minded citizens has become more pronounced in recent years, this policy of signing and marking is in dire need of review.

Economic-minded citizens argue that many signs on our low volume rural roads are not needed and should never have been put in place. For instance, on county roads the typical driver may be the farmer who lives out in the country. Those who would use the county road would be the mailmen, farm workers, neighbors, and friends. These people are motorists who are familiar with the roadway, and probably need little, if any, information from signing or marking. The converse to this argument is that people such as out-of-town guests, relatives, or emergency vehicles need some type of signing to warn of hidden sharp curves or other hazards. Perhaps both of these views are correct to some extent. The economic-minded person holds that fewer tax dollars should be spent for useless signs while his opposite claims that the signs save lives and money by alerting the uninformed motorist of certain conditions.

Environmental groups often say that highway signs detract from the beauty of the local environment. In national forests where the traffic is often extremely light, these organizations proclaim that the majestic beauty of the forests is too often broken by the starkness and nonconformity of a roadside sign with its environment. This agrument in fact is sometimes justifiable and valid; yet, the other side to this argument is that many of the motorists driving through these areas are unfamiliar with the roadway alignment. The situation may also be compounded by the driver's inattentiveness from sight-seeing. For this reason, they should be alerted to any possible situation where vehicle control may be difficult. This viewpoint also has credence.

Aesthetics is a concern for the engineer. He must be able to project the needed message with only a subtle disturbance to the environment; therefore, it is necessary to know what aesthetics means, what qualities need to be considered, and how to input the considerations into an acceptable design. All of these must be handled carefully, however, to insure a practical, economic design. Although aesthetic signing is the ultimate goal of the highway engineer, the functional aspect must not be obliterated by a desire to satisfy the environmentalists' plea for more attractive signing. A balance between a need for attractive signing and a need for effective signing must somehow be established.

Aesthetics in Signing

That which is aesthetically pleasing to one individual is not necessarily acceptable to all. Aesthetics differ for each person. Since an aesthetically pleasing object can neither be described, defined, nor even quantified, the engineer's task becomes difficult, even to the point of impossible, when trying to produce an aesthetic design. Because his goal cannot be dictated by a formula or outlined by words, he must strive to attain a functional design which does not appear hideous to the public. No guidelines have been established which will automatically guarantee success, but several generalizations which when followed will direct him toward an acceptable design. These suggestions are from Fred Ashford's The Aesthetics of Engineering Design (32) which, although meant for industrial design, may also be used for highway signing.

It has often been said that variety is the spice of life. In many cases this is true, but from an aesthetic viewpoint, aesthetic quality may be maintained along with a careful weeding out of unnecessary variety. For instance, different size signs may be placed along the highway to afford a slightly pleasing change, but with standardization of the size of signs, the aesthetic quality has been altered minutely while providing an economic optimization of space and resources. Because the difference in the sizes would have been small in comparison to the overall sign size, there would only be a subtle loss in aesthetic acceptability. The rewards received from size standardizations greatly overwhelm any benefits from any variations in size.

Aesthetics is extremely sensitive to the perceptual effect created by the figure and the ground. The figure may be defined simply as any mark or writing, and the ground is that background against which any figure or mark is seen. In the study of highway signing the written, pictorial, or numerical inscription on the sign face becomes the figure, and the background is the entire sign. Another interpretation of this concept is that the sign serves as the figure with the roadside scenery being the background. The sensitivity of the figure and ground must be balanced to avoid domination by one over the other. These elements are in constant competition for perception. In other words, if a sign is covered with an unusually high number of figures or words, the background of the sign becomes less important and consequently loses any desired effect. On the other hand, the background can dominate the figures if the background area is much larger than that of the figures. The attention is drawn to the background itself rather than specifically to the writing. In the abstract concept of the sign and the surrounding scenery, this sensitivity is more prevalent and possibly more plausible. When the sign is small and has little attention-attracting influence, the motorist may become so deeply engrossed with the environment that the sign can go completely unnoticed. However, when the size of the sign is increased until it begins to compete with attention value of the environment, the driver is more likely to perceive its existence.

Visual competition can also arise from the positioning or isolation of forms. When items are located in certain areas, the perception is accomplished more easily because of the influence on the visual attention. For instance, by placing a sign directly at the edge of a roadway, the target value is increased because it is more in line with the cone of vision. The competition here again is with the surrounding scenery. Along this same line, visual competition can be drawn by spatial orientation. Although shapes of figures may be of the same size, visual attention is directed more toward figures in which a square is rotated about the center. The abnormality automatically dominates the perceptual effect. Applying this to the field of highway signs, a uniquly-shaped sign might override the lure of beautiful scenery. The pennant "NO PASSING ZONE" sign located on the left hand side of a two-lane, two-way road is an example of the two aforementioned situations involving visual competion. The location of the left-hand side of the road within the cone of vision, plus the fact it is pennant-shaped, add to provide a distinct, attention-demanding sign. Boldness of form is another means of achieving visual competition if necessary. Despite having smaller overall dimensions, a square of bolder appearance may "stick out" more so than does a larger square. The same may be achieved in signs. By placing a small border near the edge in signs, the target value was increased over those without a border.

Engineers and designers may employ aesthetic concepts to their benefit if they so desire. By finagling with visual competition, they can afix different priorities to different objects. As a hypothetical example, a warning sign for a hidden, dangerous, upcoming curve would assume a high priority; therefore, certain policies would be followed to insure that the warning sign is seen and read in adequate time. Conversely, a sign telling of a historical marker ahead would assume a low priority. The low priority rating would be accompanied by a smaller sign with no border and a relatively poor placement.

Form must be another consideration in engineering design. Those figures which have many unequal sides require a great deal more visual scanning before the true shape may be defined. For this reason, it is best to keep designs to the lowest level of visual demand. The circle fits this level and therefore may be considered as the most aesthetic design although it may not be the most practical. The physical effort required in evaluating a circle is a continuous, unbroken one. Other than a straight line, it should also be noted the circle is the simplest figure. The complexity in reading increases with the higher degrees of form. The rounded edges provided a transition from one axis of visual scanning to another. This transition then makes the visual perception somewhat easier than that for a rectangular shape with sharp corners. Another reason for the difference in ease of perception is that a person must use his memory to store the changes in physical features. With a circle the change is constant through the entire 360 degrees. For an ellipse the rate of change of angle in visual scanning is not as great as it is for a square or a square with rounded corners, and thus follows the more aesthetic judgement for the ellipse. The most difficult form to evaluate and least aesthetically acceptable shape is the polygon with unequal sides. Besides the numerous changes in direction, the memory must store the length of each line and its orientation with respect to all others. Because of this, extra effort is required on the part of humans. The extra effort is the source for the unaesthetic judgement given to this particular form. Applying this concept to highway signing, one would think that the only shape of sign to use is the circular sign. Surely, this would provide an aesthetic design as far as the consideration of form, but the shape of signs is keyed directly to specific types of messages. For this reason several sign shapes have been chosen; however, this should not be an excuse for engineers to discount some consideration for form.

The choice of certain letters and numerals effect the aesthetic acceptability as well as the legibility. The primary aim is to present a finely-balanced, constant load for the eye to perceive and discriminate. The spacing and distribution of weight control the clarity of the message being presented. When the vertical strokes are placed closely together, the eye movements that are required become tedious and sophisticated. The result is confusion on the part of the human. The weight distribution of letters may be accomplished merely by using a constant letter stroke and a constant shade of color. A change from a black to a light gray would constitute a difference in weight distribution even though the letter stroke is held constant because the black letter receives more visual emphasis than the gray.

The choice of a typeface depends upon the function of the message. Because capital letters are seemingly more impersonal than upper-and-lower case letters, their use is generally reserved for isloated headings, functional designations, and mandatory instructions. The impersonality of capital letters is a psychological response arising probably from the association of captial letters with streetname signs, newspaper headlines, etc. On the other hand, upper-and-lower case lettering was created naturally with the development of handwriting, and therefore is more personal and appealing. The legibility of upper-and-lower case letters can be better than that for capital letters when the length of the message is considered but the height of letters must be larger in order to claim this fact.

Color is also an aesthetic consideration. The analysis of color must take into account three variables -- hue, value, and chroma. Hue is that attribute which gives a color a definite class or name such as red, green, blue, etc. Value, sometimes known as tone, is the lightness or darkness of the color. Chroma indicates the degree of departure of a given hue from a neutral gray of the same value.

Summary

The fact that in present MUTCD practice the colors, sizes, and shapes of roadway signs are not aesthetically pleasing is readily acknowledged. However, the purpose of many of these signs dictates that they must exhibit a high degree of target value. Although a dramatic alteration in signs is not feasible, the number exhibited in rural and park environments can be reduced, and in many cases, smaller signs employed. Both actions are definitely more aesthetically desirable.

As many of the National Parks and Forests contain signs whose colors are more pleasing aesthetically than standard MUTCD colors, the practice of using such color combinations should be continued, but confined to the Park or Forest. Where Park or Forest roads intersect any other Federal, State, or County road systems, standard MUTCD sign shapes and colors should be used on all intersection approaches. This practice not only provides uniformity, but also alerts the motorists to the fact that he is leaving the Park or Forest area.

RELATIVE DEGREE OF RISK OF SIGNED AND UNSIGNED CURVES

The relative degree of risk associated with reduced level of signing on curves can be evaluated based on driver characteristics in a curve maneuver. The important question to be answered is whether the reduced level of signing (general signs or no signs) contributes to potentially hazardous operations. To determine the effect of signing level, a study was conducted by Ritchie (31). Their study involved the relationship between forward velocity and lateral acceleration in curve driving. In a subsequent study, (27) Ritchie expanded the previous research to determine the driver's choice of curve speed as a function of curve and advisory speed signs.

The study was based on the actions of fifty subjects negotiating sections of roadways containing 162 curves which required deceleration from normal operating speed. Three levels of signing were evaluated: (1) no signs; (2) curve signs, and (3) curves signs w/advisory speed plaque. In addition, all curves were lumped together to obtain an overall condition. The significant results of the study were (Table 9):

- As forward velocity increased, lateral acceleration decreased, indicating that at higher speeds drivers tend to provide themselves with a greater margin of safety on curves
- Drivers were more cautious on curves without signs than on curves with signs. Mean lateral accelerations on curves with signs ranged from 0.280g to 0.124g.
- Except at very low speeds, greater lateral acceleration (0.268g to 0.161g) was produced on signed curves with advisory speed plaques than on signed curves without advisory speed plaques.
- Below 40 mph, posted advisory speeds were exceeded more often than above 40 mph.

The author's conclusion was that "...the experimental data do not support the hypothesis that the roadway signs are responsible for the inverse relationship between speed and lateral acceleration." Roadway signs serve to reduce uncertainty and increase the confidence with which the driver proceeds. Therefore, it is concluded that the reduced level of signing on curves on low volume rural roads can be affected without appreciable decrease in level of safety.

Table 9. Lateral acceleration in gravitational units (g) as a function of velocity and type of roadway sign

Condition		Forward Velocity (mph)							
		<20	20-25	25-30	30-35	35-40	40-45	45-50	50-55
All Curves	Mean	0.264	0.257	0.228	0.201	0.212	0.172	0.142	0.129
	SD	0.055	0.070	0.061	0.051	0.042	0.051	0.043	0.041
	N	9	6	11	16	20	28	35	37
With Signs	Mean	0.280	0.270	0.257	0.222	0.223	0.183	0.159	0.174
	SD	0.024	0.071	0.061	0.053	0.035	0.051	0.037	0.028
	N	2	5	6	10	13	21	18	4
Without Signs	Mean	0.259	0.193	0.193	0.165	0.192	0.140	0.124	0.124
	SD	0.062	0.	0.043	0.021	0.048	0.139	0.042	0.040
	N	7	1	5	6	7	7	17	33
With Advisory Speed	Mean	0.263	0.268	0.257	0.222	0.224	0.185	0.161	0.169
	SD	0.	0.081	0.061	0.053	0.037	0.053	0.043	0.032
	N	1	4	6	10	12	19	13	3

SIGNING AND DELINEATION ON HORIZONTAL CURVES

Aside from the elements of geometric design, warning signs, and post delineators are the primary methods of improving safety on horizontal curves. In an effort to provide guidelines for the application of signs and delineators on low volume rural roadways, existing practices, recent research, and subjective data obtained in this project were assimilated. Recommendations based on these elements were developed. Herein is contained the procedure followed in the development of recommendations and guidelines.

Signs

The MUTCD provides minimal guidelines for the application of Curve (Turn) Signs and Advisory Speed Plates. Several states have developed specific warrants for Curve (Turn) signs within the requirements of the MUTCD. These warrants require the availability of ball bank indicators or detailed curve data. The objective of this endeavor was to establish warrants for Curve (Turn) signing in lay terms to permit ready application.

The primary assumption made was that supplemental driver information is more critical in nighttime driving than in daytime. Utilizing the equation

$$S = 1.467V_1T + \frac{1.467^2[V_1{}^2 - V_2{}^2]}{2a}$$

where: S = required deceleration distance
T = perception-reaction time
V_1 = approach speed
V_2 = safe curve speed
a = deceleration rate

required distances for deceleration to safe curve speed were calculated assuming an average deceleration rate of -7 feet per second. The addition of a perception-reaction time of 2 seconds yielded the minimum distance at which a driver must be aware of an impending situation. These distances are shown for various combinations of approach and curve speeds in Table 10.

For certain combinations of approach and curve speed the roadway itself provides, in general, adequate information for proper vehicular maneuvers. It was assumed that high beam visibility distance (about 300 feet) was the upper limit at which the roadway provides adequate information. A line was drawn on Table 10 through the 300 foot contour. Distances to the upper left of the contour line require advance supplemental information, while distances to the lower right do not.

Table 10. Required deceleration distances

Safe Curve Speed (mph)	Normal approach speed (mph): 60	50	40	30	20	10
10	715	517	349	211	105	
20	669	470	303	165		
30	592	393	226			
40	484	286				
50	345					
60						

300' contour

Curve Warning Sign Warranted

Advisory Speed Plate Warranted

Calculated data points were compared graphically with field observations and the corresponding curves were found to be virtually identical. A close correlation was found between calculated critical speed differentials and those curves observed to be hazardous.

In general, it was found that at approach speeds greater than 30 mph, a differential of 10 mph between approach speed and safe curve speed required perception-reaction-deceleration distances requiring advance warning. This advance warning can be provided through the use of standard curve signs (W1-2). Speed differentials of 15 mph are characteristic of more severe curvature and should be identified with a Curve Sign (W1-2) and an Advisory Speed Plate (W13-1).

Delineators

In general, post delineators should be placed along the roadway at locations where the roadway alignment is not clearly visible to the driver at night. This practice is especially important where roadway geometrics require overt action on the part of the driver; i.e., horizontal curves. Since not all horizontal curves require delineation, certain criteria must be met to warrant this treatment.

There are many practices followed by several organizations governing the application of post delineators on horizontal curves. The MUTCD as well as several state Manuals provide strictly discretionary warrants. Taylor and Foody (22) reported that Ohio's policy of delineation of all curves with degree of curvature greater than 5 degrees was effective but inefficient. They found that curves within the range of 5 - 10 degrees of curvature, and 20 - 40 degrees central angle provided for the most efficient application of delineation.

Placement of delineators as well as application has undergone considerable scruntiny. The MUTCD and most state Manuals require, that, if delineators are used, they shall be white. Furthermore, they may be located on the right side of the roadway on left horizontal curves, and on both sides of right horizontal curves. Taylor, *et al.*, (23) found that existing practices on left horizontal curves was adequate, but that crystal delineators on both sides of the roadway on right horizontal curves produced "visual clutter." On that basis, they proposed a two-color system in which delineators would be placed only on the outside of the curve -- white on left curves and yellow on right curves.

Delineators spacing is another important factor. There are nearly as many spacing practices as there are responsible organizations. Most practices fall within the guidelines of the MUTCD:

$$S = 3\sqrt{R - 50}$$

All spacings are based on the need to see several (typically, three) delineators at all times.

Taylor, et al., (23) found that, although the MUTCD spacing was adequate, a greater spacing of $4\sqrt{R}$ was also adequate. On a 10 degree curve with a central angle of 45 degrees, these spacings would yield 9 and 6 delineators, respectively. Therefore the application of the $4\sqrt{R}$ spacing results in considerable savings. Further, for the curve mentioned, there would be three delineators visible at all times for the assumed headlight distance of 300 feet.

There should be more definite guidelines for the application and placement of post delineators on horizontal curves. Application on curves with degree of curvature greater than five degrees and a central angle greater than twenty degrees is most efficient. The current practices of delineator placement on curves is inefficient and sometimes produces "visual clutter." A practice of delineation of the outside of curves, possibly with a two-color system, has been recommended. The existing MUTCD spacing requirements are adequate but not efficient. A revised spacing of $S = 4\sqrt{R}$ has been shown to be adequate.

WINDING ROADS

A characteristic of many low volume rural roads is the multiplicity of horizontal curves. Many of these curves fall within the warrants of curve warning signs. However, to sign all of these curves would be costly as well as aesthetically displeasing. For these reasons, a general sign indicating a roadway section with numerous curves is desirable. The Manual on Uniform Traffic Control Devices (MUTCD) includes such a sign - Winding Roads (W1-5). However, the warrants and limitations of the application of this sign are not cost-effective for use on low volume rural roads. Therefore, it was undertaken to develop less restrictive warrants for the application of the Winding Roads sign.

The MUTCD and the Texas Manual on Uniform Traffic Control Devices (TMUTCD) contain warrants requiring that a "Winding Roads" section of roadway include five or more curves warranting curve signs separated by tangent sections of no more than 600 and 400 feet, respectively. Assuming that an average curve length is about 700 feet, the MUTCD and TMUTCD warrants indicate a requirement of 4 and 5 fairly severe curves per mile, respectively. In general, the warrants reflect extended areas of inadequate passing sight distance. For the purposes of this report, lack of adequate passing sight distance shall not indirectly govern the application of Winding Roads signs.

A basic assumption for the development of guidelines for winding roads is that they should be placed on roadway sections in which a driver cannot maintain a constant running speed. Assuming a driver slows to 15 mph below his approach speed in a curve, and his acceleration rate out of the curve is approximately 1.4 mphps, 10-11 seconds will have elapsed before he regains running speed. At 75 fps (50 mph) average speed, he will have traveled 750-800 feet during acceleration. Allowing 300 feet for deceleration to safe curve speed for the next curve, the total distance traveled between curves is 1000-1100 feet.

Again assuming 700' curve length of a section including three such curves and two tangents is approximately 4300 feet. The inclusion of another curve and the corresponding tangent section yields a roadway section of approximately one mile in length.

A "Winding Roads" section thus includes a section of roadway in which drivers may reach but not maintain running speed. Since the driver will be making continuous speed adjustments, he should be more alert to impending curve situations. In addition, the less restrictive tangent lengths would provide adequate passing sight distance in some instances. Therefore, a Winding Roads condition is not synonymous with extended no passing zones.

INTERSECTION CONTROL NEEDS

Introduction

One of the major criteria for the application of intersection control on low volume rural roads is the economic justifiability of such control. A necessary consideration in this justification is the probability of conflict at the intersection of two low volume rural roads.*

For the purpose of analysis, the following assumptions are made:

- "Conflict: is defined as that maneuver of vehicle B such that the driver of vehicle A must change speed or direction to avoid collision.
- Assume average speed is 40 mph or approximately 60 fps.
- Any two vehicles approaching the intersection from conflicting directions such that the second vehicle would enter the intersection within three seconds after the first vehicle enters the intersection are said to be in "conflict," i.e., one or both vehicles must make a speed change maneuver to provide comfortable clearance.
- Effects of sight distance are not considered.
- All vehicles arrive during a 12-hour period from 7 a.m. to 7 p.m.**
- All arrivals follow a Poisson distribution.
- The possibility of vehicles arriving on three approaches within a three-second interval is negated as the probability of such occurrence is a maximum of 2.01×10^{-5} for a 400 by 400 intersection.

Probability Determination

The probability that two vehicles will be in conflict is the product of the probability that either vehicle is in the intersection during the interval Δt. Or,

$$\begin{aligned} P(\text{conflict}) &= P(\text{vehicle A in intersection during } \Delta t) \times \\ &= P(\text{vehicle B in intersection during } \Delta t) \end{aligned}$$

---

* It is assumed that the application of STOP or YIELD control at the intersection of a low volume rural road and a higher volume facility will be governed by the higher volume facility.

** It is probable that all vehicles do not arrive between 7 a.m. and 7 p.m., but since this assumption covers the worst condition, it is used here.

Probability of at least one Arrival, P(X) = 1 - Probability of No Arrivals P(0)

$$P(X) = \frac{e^{-m} m^{x}}{x!}$$

$$P(0) - \frac{e^{-m} m^{o}}{0!}$$

Flow rate on a facility of 100 ADT = .0023 vps. For a 3-second interval the expected volume would be .0069 veh. Then,

$$P(0) = \frac{e^{-.0069} .0069^{0}}{0!} = .9931$$

$$P(X) = 1 - P(0) =$$

The probability of two vehicles arriving within 3 seconds of each other is the product of the probability of arrival on both facilities:

$$\text{Probability of Conflict, } P(C) = P(X_1)\ P(X_2)$$

For the two 100 ADT facilities,

$$P(C) = (.00687)\ (.00687) = 4.73 \times 10^{-5}$$

Multiplying by the number of 3-second intervals in a 12-hour day yields the expected number of conflicts in a 12-hour day:

$$E(C) = (4.73 \times 10^{-5})\ (14{,}400) = 0.68 \text{ conflicts/12-hour day}$$

Or, on the average, 2 conflicts every 3 days. By varying the ADT in increments of 50 on both facilities, the expected number of conflicts is determined for all ranges of volume and is shown in Table 11. The expected number of conflicts shown in Table 11 indicates a wide range of values. Values of E(C) vary from 0.04 conflicts per day for combined ADT of 50 vpd to 10.67 conflicts per day at combined ADT of 800 vpd. The highest value of E(C) for a particular ADT combination is found where the volumes are split 50/50, as expected. For example, for a combined ADT of 300 vpd, E(C) is only 0.47. This variation indicates that intersection control becomes increasingly important as the volumes of the two intersecting facilities approach equality.

The next step in determining economic justification is determination of the probability of an accident, given a conflict. A study conducted by General Motors Research Laboratories (30) showed 33 accidents occurred in 100,000 conflicts, or

Probability of an Accident, given a Conflict [P(A,C)] = .00033

Table 11. Expected number of conflicts per day E(C)?

ADT - Facility B	ADT - Facility A: 50	100	150	200	250	300	350	400
50	.17	.34	.51	.68	.85	1.02	1.18	1.35
100	.34	.68	1.02	1.36	1.69	2.03	2.36	2.70
150	.51	1.02	1.53	2.03	2.54	3.04	3.54	4.04
200	.68	1.36	2.03	2.70	3.38	4.04	4.71	5.37
250	.85	1.69	2.54	3.38	4.21	5.04	5.88	6.70
300	1.02	2.03	3.04	4.04	5.04	6.04	7.04	8.03
350	1.18	2.36	3.54	4.71	5.88	7.04	8.20	9.35
400	1.35	2.70	4.04	5.37	6.70	8.03	9.35	10.67

Other data indicated that P(A,C) ranges from .00023 to .00035, therefore, to examine "worst case" conditions, a value of P(A,C) = .00035 was used. Then, the probability of an accident P(A) is given by:

$$P(A) = P(A,C)P(C)$$

For the two 100 ADT facilities:

$$P(A) = .00035\ (4.75 \times 10^{-5}) = 1.66 \times 10^{-8}$$

Multiplying by the number of 3-second intervals, 14,400 yields the expected number of accidents in one day:

$$(1.66 \times 10^{-8})\ 14{,}400 = .000239$$

Multiplying by 365 yields the expected number of accidents in one year, E(A):

$$E(A) = (365)\ (.000238) = .087$$

The expected number of accidents per year was shown in Table 12 for all ranges of ADT considered. It can be seen from the table that one or more expected accidents per year are generated by ADT combinations of 700 vpd or greater. For ADT combinations less than 700 vpd, less than one accident per year is expected.

Once probability of accidents has been determined, it is necessary to estimate the costs associated with typical accidents. The primary factor governing accident cost is severity. Data from a study by Burke (25) showed little variation in severity over the ADT range 0-400.

Injury ratio, however, was found to increase with speed (33), as did the proportion of fatalities (26). Combining the results of these studies, a weighted accident cost equation was developed:

$$\text{Cost} = F_P(A) = F_I(B) = F_F(C)$$

where: F_P = proportion of property damage only accidents
A = average cost of property damage only accidents = \$318 (23)
F_I = proportion of injury accidents
B = average cost of injury accidents = \$1955 (23)
F_F = proportion of fatal accidents
C = average cost of fatal accidents = \$13, 781 (23)

The proportion of injuries and fatalities was obtained by determining the proportion of injuries (by speed) from Ref. 33 and multiplying by the fatality/injury ratio from Ref. 26. Thus for 20 mph, the proportion

Table 12. Expected number of accidents per year, E(A)

ADT - Facility B	ADT - Facility A: 50	100	150	200	250	300	350	400
50	.022	.043	.065	.087	.109	.130	.151	.172
100	.043	.087	.130	.174	.216	.259	.301	.345
150	.065	.130	.195	.259	.324	.388	.452	.516
200	.087	.174	.259	.345	.432	.516	.602	.686
250	.109	.216	.324	.432	.538	.644	.751	.856
300	.130	.259	.388	.516	.644	.772	.899	1.026
350	.151	.301	.452	.602	.751	.899	1.048	1.194
400	.172	.345	.516	.686	.856	1.026	1.194	1.363

of injuries was 25 percent (33) leaving 75 percent as property damage only. According to Ref. 26, the fatality/injury ratio for 20 mph is 0.009. Then the product of 0.009 and 0.25 is the proportion of fatalities, or 0.002. Thus, for 20 mph, the proportional factors are: $F_P = 0.750$, $F_I = 0.248$, and $F_F = 0.002$. Calculations are similar for proportional factors for the remaining speed groups. Proportional factors, combined with the respective costs for each type accident, generated an average cost per accident for each speed group.

Cost/Accident (20 mph) = .750 ($318) + .248 ($1955) + .002 ($13,781) = $750

Table 13 shows the weighted average cost per accident for the five speed groups.

Average yearly accident cost per intersection, by speed for each ADT combination, is given by the product of expected number of yearly accidents, E(A) (Table 12), and weighted average cost per accident (Table 13). These costs, shown in Tables 14 through 19 are compared with expected costs of 2-way stop control. The costs of 2-way stop control included expected accident costs (approximately 1/5 that of no control) and increased annual motor vehicle operating costs due to stop control.

The costs associated with 2-way stop control include expected annual accident costs and additional annual motor vehicle operating costs. Additional operating cost is the difference between 1) the cost of continuing through the intersection at the approach speed and 2) the cost of slowing to a stop from the approach and returning to running speed. As would be expected, the costs of stopping and regaining running speed increase with increases in running speed. Table 14 shows additional operating costs for each speed group and the complication of expected cost of 2-way stop control on a 100 ADT facility.

The 2-way stop control costs are shown in Tables 15 through 19.

Careful examination of the estimated costs tables reveals that in all cases, the expected annual accident costs associated with no control are less than the accident and operating costs associated with 2-way stop control for combined ADT's of 200 vpd. At higher ADT's these expected costs become equal, and higher still, the no-control alternative becomes more expensive. The breakpoints in expected cost occur at progressively higher ADT's as speed increases. The breakpoints for the five speed groups are:

Table 13. Weighted average cost/accident

Speed (mph)	Proportional Factors F_P	F_I	F_F	Weighted Average Cost/Accident
20	.750	.248	.002	$ 750
30	.720	.277	.003	812
40	.660	.322	.008	969
50	.580	.400	.020	1,242
60	.410	.783	.077	1,733

Speed (mph)	Combined ADT (vph)
20	300
30	520
40	650
50	700
60	720

The calculation of these breakpoints is derived by equating costs of no control and costs of 2-way stop control, as represented in the following equation:

$$E(A)\cdot C_A = ADT\cdot 365\cdot C_S - 0.2\,[E(A)\cdot C_A]$$

which can be simplified to:

$$0.8\,[E(A)\cdot C_A] = T_Y\cdot C_S$$

Table 14. Expected annual cost of 2-way stop

Approach Speed (mph)	Operating Cost Per Stop (5) ($)	Stops Per Year (100 ADT)	Annual Operating Cost ($) Col. A	Average Cost/Per Accident ($)	Expected Number of Accidents	Expected Annual Accident Cost ($) Col. B	Expected Annual Cost of 2-Way Stop ($) Col. A + Col. B
20	.0022	36,500	81	750	.0174	13	94
30	.0040	36,500	145	812	.0174	14	159
40	.0059	36,500	216	969	.0174	17	233
50	.0083	36,500	302	1,242	.0174	22	324
60	.0116	36,500	422	1,733	.0174	30	452

Table 15.

Estimated accident costs per year
approach speeds - 20 mph

ADT - Facility A

ADT - Facility B	0	100	200	300	400
100		65 94*	130 107*	194 120*	259 133*
200		130 107*	259 213*	387 238*	514 264*
300		194 120*	387 238*	579 357*	770 395*
400		259 133*	514 264*	770 395*	1022 526*

* Note: Numbers with asterisk reflect expected annual accident cost and additional motor vehicle operating cost with 2-way STOP control.

Table 16.

Estimated accident costs per year
approach speeds - 30 mph

ADT - Facility A

ADT - Facility B	100	200	300	400
100	70 159*	141 173*	210 187*	280 201*
200	141 173*	280 346*	419 374*	557 401*
300	210 187*	419 374*	627 560*	833 602*
400	280 201*	557 401*	833 602*	1107 802*

* Note: Numbers with asterisk reflect expected annual accident cost and additional motor vehicle operating cost with 2-way STOP control.

Table 17.

Estimated accident costs per year
approach speeds - 40 mph

ADT - Facility A

ADT - Facility B	100	200	300	400
100	$ 84 233*	$169 250*	$251 266*	$ 334 283*
200	$169 250*	$334 499*	$500 532*	$ 665 565*
300	$251 266*	$500 532*	$748 798*	$ 994 847*
400	$334 283*	$665 565*	$994 847*	$1320 1129*

* Note: Numbers with asterisk reflect expected annual accident cost and additional motor vehicle operating cost with 2-way STOP control.

Table 18.

Estimated accident costs per year
approach speeds - 50 mph

ADT - Facility A

ADT - Facility B	100	200	300	400
100	108 324*	216 345*	322 366*	428 388*
200	216 343*	428 689*	641 731*	852 873*
300	322 366*	641 731*	959 1097*	1274 1160*
400	428 388*	852 774*	1274 1160*	1693 1547*

* Note: Numbers with asterisk reflect expected annual accident cost and additional motor vehicle operating cost with 2-way STOP control.

Table 19.

Estimated accident costs per year
approach speeds - 60 mph

ADT - Facility A

ADT - Facility B	0	100	200	300	400
100		151 452*	302 482*	449 512*	598 542*
200		302 482*	598 965*	894 1024*	1189 1083*
300		449 512*	894 1024*	1338 1536*	1778 1624*
400		598 542*	1189 1083*	1778 1624*	2362 2162*

*These numbers reflect expected annual accident cost and additional motor vehicle operating cost with 2-way STOP control.

where: $E(A)$ = expected number of yearly accidents with no control (Table 12)

C_A = weighted average cost per accident (Table 13)

T_Y = yearly traffic volume = ADT X 365

C_S = additional motor vehicle operating cost with 2-way stop control

The solution of this equation is an iterative process in which T_Y is varied, as are the other variables as they change with T_Y, until the two sides of the equation are equal. The ADT at which equality is reached is the economic breakpoint.

From a strictly economic standpoint, therefore, for ADT combinations above the breakpoint for each speed group, the implementation of 2-way stop control is advisable. There are other necessary considerations which must be made in determining the guidelines for intersections which will be discussed in subsequent sections of this report.

Application of Stop Signs

STOP signs should be placed on low volume roads (paved or unpaved) intersecting paved highways, provided that the low volume road meets one or more of the following criteria:

The low volume road:

- o serves ten or more residences;
- o has an Average Daily Traffic (ADT) of 50 or more; or
- o is five miles long or longer.

The above guidelines should be followed UNLESS it can be shown that:

1) The combined average daily traffic for the two intersecting roadways is less than that shown below for the corresponding lower approach speed of the two facilities;

Approach Speed	Combined ADT
20 mph	300 vpd
30 mph	500 vpd
40 mph	640 vpd
50 mph	700 vpd
60 mph	720 vpd

AND, 2) The sight distance on each approach is at least that shown below for the corresponding approach speed:

Approach Speed	Sight Distance*
20 mph	90 feet
30 mph	130 feet
40 mph	180 feet
50 mph	220 feet
60 mph	260 feet

* As specified by AASHTO

Sight distance is defined here as a triangle of clear visibility with legs of a length equal to the distance shown for the corresponding speed shown. This triangle shall apply from all directions of approach.

Example: Approach speeds on two intersection facilities are 50 mph and 40 mph, respectively. A vehicle approaching the intersection on the 50 mph facility must, at a distance of 220 feet from the intersection, have clear visibility throughout a cone of vision extending 180 feet in each direction along the crossing roadway. (See Figure 11)

For intersections which meet the requirements in (1) above for no control, but do not meet the requirements of (2) above (i.e., inadequate sight distance), a standard Cross Road sign, W2-1, may be used in advance of the intersection in lieu of 2-way STOP control.

The requirements for intersection control given above can be determined graphically from Figure 12. The procedure is as follows:

Step 1. Enter combined ADT in part (A) and project horizontally to intersect with lowest approach speed. If the intersection of these two lines is above the curve (shaded area), stop here and install STOP signs on the minor approaches(es).

Step 2. If below the curve, project intersection point downward into part (B).

Step 3. Enter shortest sight distance on lower speed approach and project horizontally to intersect line drawn in Step 2. If this intersection point lies below the line, no control is needed. If the intersection point lies above the line (shaded area), a standard Cross Road sign is needed on all approaches.

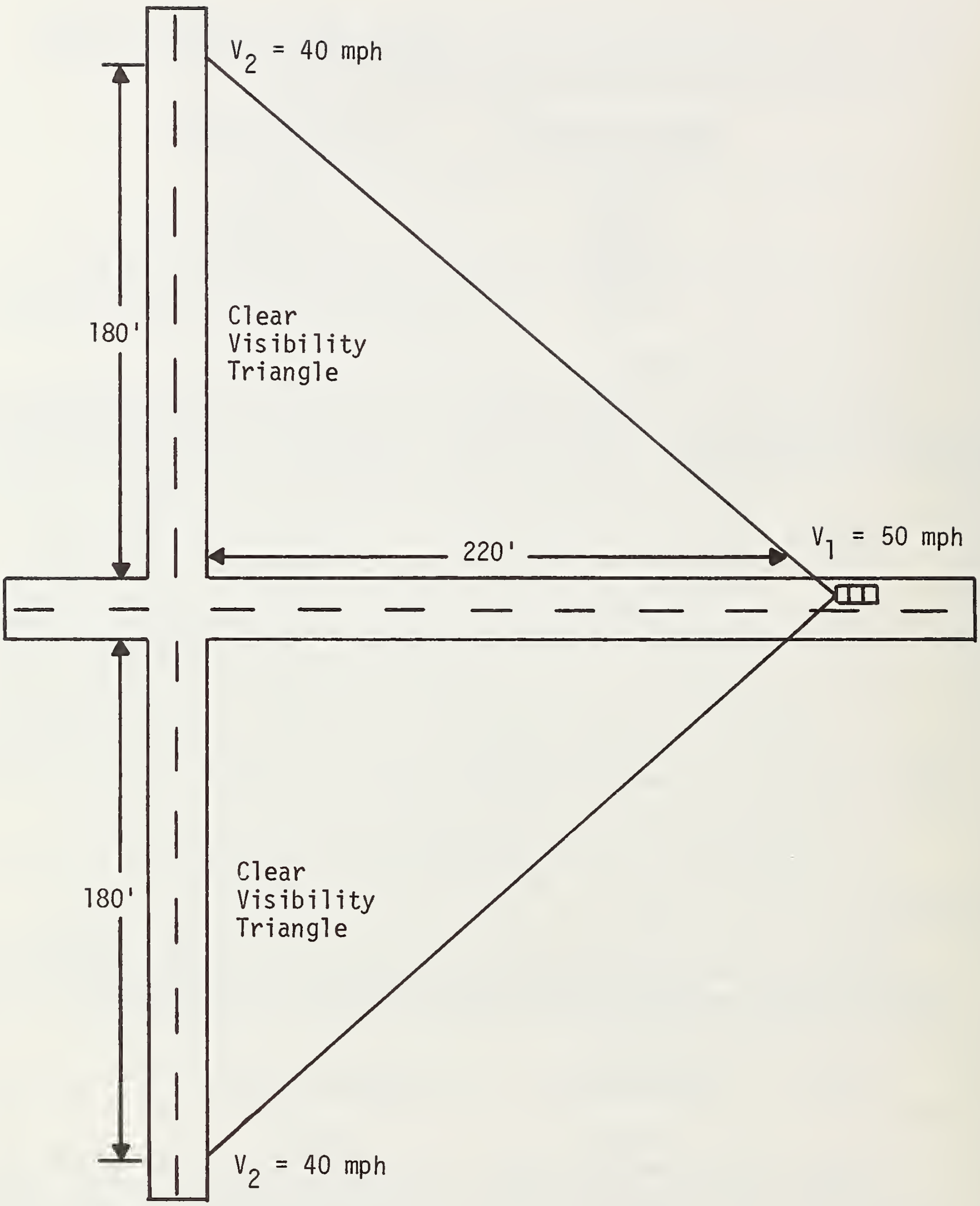


Figure 11. Required Sight Distance Triangle for No Intersection Control

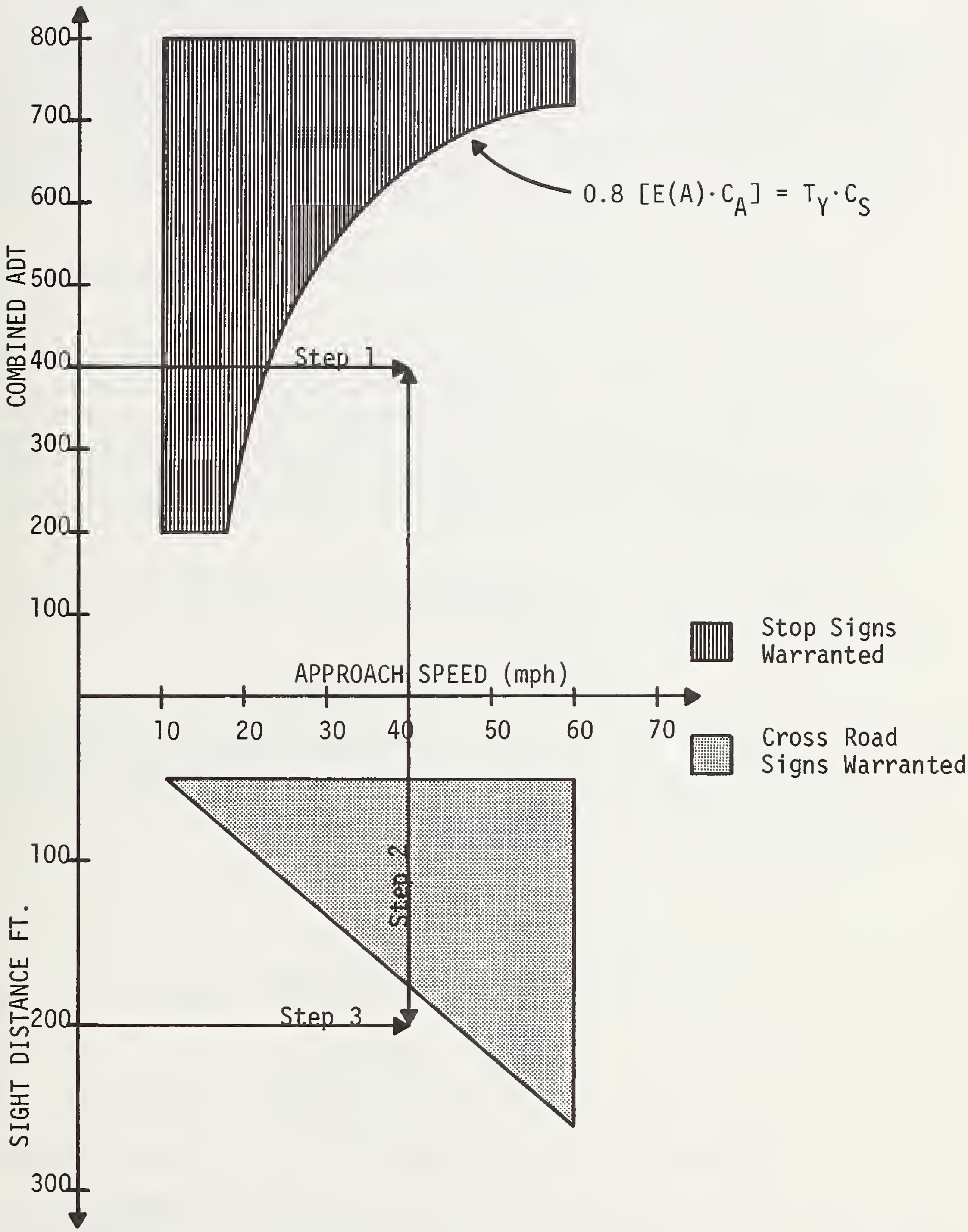


Figure 12. Intersection Signing Nomograph

PROBABILITY OF CONFLICT IN PASSING MANEUVERS

The evaluation of risk involved in reduced signs and markings involves a comparison of MUTCD standards and the reduced level for Low Volume Rural Roads. For a conservative estimate, it will be assumed that standard signs and markings will be complied with 100 percent; thus, the probability of conflict (in a no-passing zone) will be zero. It will then be necessary to determine the probability of conflict for total noncompliance at reduced levels of signing and marking. This technique will produce an unrealistically conservative estimate which will be adjusted later.

The basic situation for development of probability of conflict is as follows:

A driver in vehicle A, traveling 50 mph, overtakes vehicle B, traveling 40 mph. Without regard for safe passing sight distance, the driver in vehicle A pulls into the opposing traffic lane to pass vehicle B. Before vehicle A can return to the right lane, vehicle C, traveling in the opposite direction, comes into conflict with vehicle A. The necessary determination in this evaluation is the probability of the above situation occurring.

To begin with, the probability of vehicles A and B being in the above passing situation is the probability of simultaneous arrival of two or more vehicles, given by:

$$P(X) = 1 - [P(0) = P(1)]$$

For a 200 ADT facility with a 50/50 directional distribution, the ADT in either direction is 100. The arrival rate (m) equals .0023 vehicles per second. Assuming a headway of approximately 2 seconds, then arrival rate in Δt = .0046.

$$P(X) = \frac{e^{-m} m^{x}}{x!}$$

$$P(0) = \frac{e^{-.0046} .0046}{0!} = .99541$$

$$P(1) = \frac{e^{-.0046} .0046}{1!} = .00458$$

Therefore, $P(\geq 2) = 1 - [P(0) = P(1)] = 1 - .99999 = .00001$

times the number of 2 second intervals in a 12-hour day.

$$P(\geq 2) \times 21{,}600 = .216$$

In other words, the probability of any two vehicles being close enough for the following vehicle to pass in any one day is .216.

Assuming that the following vehicles passes at his constant speed of 50 mph, the length of time that vehicle A is encroaching on the opposing lane is determined as follows:

$$d = 1.47\ vt$$

where: d = distance traveled in left lane

v = average speed

t = time left lane occupied

therefore: $$t = \frac{d}{1.47v}$$

At the assumed speed of 50 mph, d is approximately 800 ft.

Therefore, the length of time vehicle A encroaches upon the left lane is:

$$t = \frac{800}{1.47\ (50)}$$

$$t = 10.9 \text{ or } 11 \text{ seconds}$$

If an opposing vehicle arrives in that 11-second interval, there will be a conflict. The probability of an arrival in the opposing lane is given by:

$$P(1 \text{ or more}) = 1 - P(0)$$

$$P(0) = \frac{e^{-m} m^{x}}{x!}$$

$$m = .0253$$

$$P(0) = \frac{e^{-.0253} .0253^{0}}{0!}$$

$$P(0) = .97502$$

$$P(1 \text{ or more}) = 1 - P(0) = P(A)$$

$$P(A) = .02498$$

The probability of the passing maneuver occurring during the 11-second critical interval is:

$$P(P)\ \frac{11}{2} \times .00001 = .000055$$

$$P(C) = .13739 \times 10^{-5}$$

The probability of such an occurrence during a 12-hour period equals P(C) times the number of 11-second intervals in that period:

$$P(C_{12}) = (.13739 \times 10^{-5})\ (3927)$$

$$= 539.6 \times 10^{-5}$$

$$= .005396$$

There are several adjustments which must be made to reflect a more realistic probability of conflict. The calculated probability assumes passing along the entire roadway, whereas it actually applies to situations of limited sight distance. Assuming that there is an average of 30 percent passing sight distance on the roads in question, the P(C) becomes:

$$P(C_{12}) = .005396\ (.07) = .00377$$

However, this figure still represents 100 percent non-compliance. A 50 percent compliance would further reduce the probability of conflict:

$$P(C_{12}) = .003777\ (.5)$$

$$= .001889$$

Over a 365 day period, the P(C) becomes:

$$P(C_y) = .001889\ (.365)$$

$$= .689$$

Therefore, on the average, twice in every three years a passing conflict will develop.

DRIVER COMPREHENSION SURVEY

Of primary importance in the development of new signs and pavement markings is the driver response to such devices. Current trends toward diagrammatic signing can greatly enhance the multi-lingual effectiveness of control devices. However, if such signs are not understood by a large portion of the driving public, their effectiveness is minimal. The same applies to new verbal messages and pavement markings. Therefore, before new control devices are recommended for widespread application they must be thoroughly tested and evaluated.

In an effort to evaluate the potential effectiveness of the conceptual control devices developed in this project, questionnaires were distributed to 270 drivers. These questionnaires were designed to test the drivers' reaction to the proposed signs and markings. The results of the questionnaire studies showed that nearly all of the proposed devices were readily recognized. They also give an indication of drivers' preference for a specific device to alert him to a specific situation. And, finally, the questionnaire results revealed those situations in which drivers feel a need for some type of regulatory or warning device. Following is an analysis of the results of the questionnaire studies. A copy of the complete questionnaire and data analysis and can be found in Appendix C.

Signs

The initial thrust in sign validation concerned the passing/no-passing situation (Questions 5-9). First, subjects were shown four signs containing two passing warnings and two passing regulation messages, and were asked to indicate which were restrictive and which were permissive (Questions 5 and 6). Responses to both were highly significant at the .001 level. Drivers readily distinguished between the regulatory and warning messages even though one of the regulatory messages was displayed on a warning sign shape (Sign C).

Subjects were then asked to indicate what the message "PASSING HAZARDOUS" on a warning sign meant (Question 7). A vast majority correctly interpreted the meaning as "passing is allowed, only with extreme caution." The results of the chi-square test were highly significant at the .001 level.

Response to Question 8 revealed that a majority of the drivers preferred pavement markings to signs to indicate "NO PASSING."

Finally, drivers were asked to indicate whether passing warning was necessary in each of four roadway situations (Question 9). The respondents indicated that no warning was needed on either paved or unpaved roadways that were generally straight and level. However, the responses showed that warning was necessary on both straight roadways over rolling hills and winding roadways in mountainous terrain.

In general, response to passing warning questions indicate that although warning is necessary in some locations and that marking is preferred, general passing advisement signing is readily recognized and can be used effectively in lieu of more intensive signing and marking in no-passing zones. Field testing of these general warning signs to assess motorist compliance should be undertaken before such signs are released for wide-spread use.

The second major thrust in sign validation was in the area of general versus individual curve warning. Four questions (10-13) were posed to assess driver comprehension of and preference for certain general warning signs and to determine whether drivers felt a need for general or individual warning signs in each of four roadway situations.

Responses to Questions 10 and 11 showed that drivers readily understood the meaning of both "RURAL ROAD" and "WINDING ROAD" signs. Response to these questions was highly significant.

However, in selecting a sign to be used in this general context (Question 12), the respondents rather unexpectedly chose "SLOW-CURVES" (Sign D). Response to that sign was significant at the .001 level. Further validation of this sign is needed though, as it received only a plurality of responses.

Decisive results were obtained for only one of four situations posed in Question 13. The majority of respondents opted for a general warning sign on paved roadways that were basically straight and level. Responses to the same question for winding roadways in various terrains received almost equal numbers of responses for general and individual warning signs.

Motorist comprehension of these signs and analyses presented previously indicate that general warning signs can be used to effectively communicate the necessary curve warning on most roadways.

Two new diagrammatic signs designed to communicate "Narrow Bridge" were presented to the respondents. Response to Questions 14 and 16 indicated that one new "Narrow Bridge" sign is understood and preferred by a significant margin. The other diagrammatic sign (Question 15) was interpreted to mean "Low Water Crossing." Response to all three questions was significant at the .001 level.

Data obtained for four "Narrow Bridge" situations indicated that

"Narrow Bridge" warning is needed for one-lane bridges on curving roadways, eihter paved or unpaved. Responses to the other two situations, a paved, two-lane, curving roadway, and an unpaved, one-lane, straight roadway, were not conclusive.

Summarily, a diagrammatic "NARROW BRIDGE" sign can be used effectively and should be applied in advance of one-lane bridges which are located such that the driver might be surprised, such as on a sharp horizontal curve. The necessity for the same signs in advance of two-lane bridges or bridges on straight roadways cannot be assessed from these data.

The last sign category to be considered was that concerning stop control at four rural intersections (Question 20-23). The results were more nearly conclusive on the lower and upper ends of the roadway classification. A majority of respondents indicated that a STOP sign was needed at the intersection of a paved highway and an unpaved road, but the difference was slight. The results of Question 20 (two unpaved roads) are clouded somewhat by a majority choice for "sign needed" at two unpaved roads in Question 22. A possible explanation is that in Question 20 the respondents were eliminating a sign on their approach, and in Question 22 they were requiring a sign on the crossing roadway. Thus the subjects responses may have been an extension of "I don't want to stop, but I want everyone else to."

Markings

The primary objective in the pavement markings portion of the survey was to determine whether a less expensive no-passing zone marking would be understood. Questionnaire results showed that the proposed "double-narrow" yellow line does convey a prohibitive meaning and could be used effectively in no-passing zones.

Response to Question 1 showed that 68.5 percent of the subjects viewed the "double-narrow" line as a prohibitive marking, while in Question 2 only 6.7 percent interpreted that line as a permissive marking. The prohibitive nature of the line was confirmed in Question 3 where a large majority of respondents indicated that the "double-narrow" line did not differ in meaning from the normal double line.

The same did not hold true, however, for the single yellow line. The meaning of that line is apparently confusing, as evidenced by a 41.6 percent "restrictive" response in Question 1 and a 30.7 "permissive" response in Question 2. A significant "Yes" response to Question 4 indicated that the single yellow line carries a meaning different from a double line.

Questions 18 and 19 were designed to ascertain whether motorists recognize the roadway geometry that corresponds to certain delineator patterns. The results of the two questions showed that a majority of motorists readily recognize the delineator patterns used on horizontal curves and on bridge approaches.

There were three questions on the original questionnaire which dealt with signs and markings used in advance of railroad grade crossings. As the grade crossing problem is very complex, reliable data could not have been obtained in three short questions. Thus those three questions were not administered.

Major Findings

A combined questionnaire and slide presentation designed to validate project results was administered to 270 drivers. From the data obtained, the following points are drawn:

1. Motorists readily distinguished between passing warning and passing regulation signs.
2. Motorists correctly interpreted the "PASSING HAZARDOUS" warning sign.
3. Passing warning was desired in rolling and mountainous terrain but was not desired on roadways that were generally straight and level.
4. General curve warning signs were correctly interpreted by a significant number of respondents.
5. A majority of motorists chose "SLOW-CURVES" as the "best" general curve warning sign.
6. With respect to the need for general or individual curve warning signs, the only significant result was that a general warning sign should be used on roadways that are basically straight and level.
7. A decisive number of respondents correctly interpreted a diagrammatic "NARROW BRIDGE" sign and chose it as the "best" sign for warning of a narrow bridge.
8. "NARROW BRIDGE" warning was shown to be needed in advance of one-lane bridges on curving roadways, both paved and unpaved.
9. Respondents indicated that STOP signs are not needed at the intersection of unpaved roads, and that STOP signs are needed at the intersection of paved roads.
10. Double-narrow yellow lines were recognized as restrictive markings, and did not differ in meaning from normal double yellow lines.
11. A single yellow line was recognized as having a different meaning than a double yellow line.
12. Respondents accurately interpreted the meanings of delineators placed on horizontal curves and bridge approaches.

SUMMARY

Several types of low volume roadways (less than 400 ADT) exhibiting a wide range of both design and functional characteristics were investigated in this study. These facilities consisted of farm-to-market and country roads which provide access to rural communities and serve as the major avenue for agriculture commerce. They also included forest and park roads which are necessary for the operation, maintenance, and accessibility of national and state forests and parks. All of these roadways comprise a large percentage of the total U. S. highway mileage under maintenance. Since the probability of an accident on these roadways is low, this study attempted to define what warning and regulatory signs and markings would be needed to adequately balance safety with road economy.

To meet the study objective, the various types of low volume rural roads were initially classified by system (Federal, state, or county controlled) and type of surface (paved and unpaved). Using a modified form of driver task analysis, these various classes of roads were then analyzed with regard to their travel characteristics to determine the required level of warning and regulatory signs and markings needed for satisfactory operation and safety. Specifically, costs of roadside signing and marking, aesthetics, and relative degree of risk were considered in determining the needed signs and markings. This analysis led to guidelines for the application of stop signs, curve warnings, and passing zone signs and markings. These guidelines were validated by testing 270 driver reactions to the proposed signs and markings.

The actual guidelines developed follow:

Intersections

Stop signs should be placed on low volume rural roads (paved or unpaved) intersecting paved highways, provided that the low volume road meets one or more of the following criteria:

1. Serves 10 or more residences

2. Has an Average Daily Traffic of 50 or more, or

3. Is 5 miles long or longer.

The criteria are valid for stop sign placement unless it can be shown that the relationship between ADT, sight distance, and approach speed dictates other control measures. This determination can be made using the intersection control graph shown on Page 81 and described on Page 79.

Horizontal Curves

Curve signs should be placed in advance of all curves with intersecting angles of 45 degrees or more on paved roadways, and 60 degrees or more on unpaved roadways unless it can be shown that:

1. The posted speed limit is 35 mph or less; or

2. The combination of noraml approach speed and safe curve speed requires a perception-reaction-deceleration distance of less than 300 feet (see table on Page 60).

Advisory Speed Plates should be used in conjunction with Curve Warning signs when the safe curve speed is 5 mph below that speed warranting a curve sign.

No Passing Zones

Although the probability of conflict in a passing maneuver is negligible, the elimination of all signs and markings relative to passing does entail some risk. Yet the degree of risk involved does not appear to justify the expense of standard MUTCD striping.

A "PASSING HAZARDOUS" warning sign should be used to indicate extended sections of inadequate passing sight distance on all unmarked paved roadway and all unpaved roadways. Such signs should have attached a supplementary plate bearing the legend "NEXT XX MILES," indicating the length of the section. Subsequent "PASSING HAZARDOUS" signs and supplementary plates should indicate the number of miles remaining in the section from that point.

If centerline definition is desired on paved roadways with insufficient passing sight distance, a double narrow line may be used in lieu of the "PASSING HAZARDOUS" signs. The double narrow line consists of two 1¼-inch yellow lines separated by a 1-inch space. This line should be used only for extended sections of insufficient passing sight distance; intermittent sections of restricted sight distance within which striping is deemed necessary should be striped as per present MUTCD guidelines. As vehicle wheel paths on roadways less than 20 feet wide tend to overlap the centerline and obliterate painted pavement markings, such roadways should not be striped.

APPENDIX A

TAPE 1 - SECTION 1 - ARKANSAS

Location : SH 298, east of Story, Arkansas
Length : 3.0 miles
Classification: Paved, marked State
ADT: 210 vehicles
General Description: Sharp winding curves, hilly terrain
Geometry: Rolling vertical alignment; curves mainly in cut sections
Pavement: 29' pavement width; outside edge of pavement shows little use
Signing: Adequate marking signs; larger info signs; bridge warning adequate
Marking: Adequate marking; no shoulder stripe
Safety: Sight distance reasonable for terrain
General Comments: Tracking on curves; hard to maintain curves at warning speed; no traffic; no delineation, possibly needed at night; average speed 40-50 mph

TAPE 1 - SECTION 2 - ARKANSAS

Location: Corp of Engineers road into SH 27 Use Area
Length : 2.0 miles
Classification: Paved, unmarked Federal
ADT: 30 vehicles
General Description: Park and recreation type road; ADT possibly higher than shown
Geometry: Sharp horizontal and vertical curves
Pavement: 16' Pavement width; fair condition
Signing: Park info signs; no speed or warning signs; "Lake Ahead" sign
Markings: None; no delineation
Safety: Edge of road terrain hazardous; no margin for error
General Comments: Road narrow; vehicle alignment must be maintained strictly because of edge of road terrain; curves deceptive; possibly need both warning signs and/or delineation; average speed 30 mph

TAPE 1- SECTION 3 - ARKANSAS

Location: National Forest Highway, Southeast of Washita, Arkansas
Length: 5.6 miles
Classification: Paved, marked Federal
ADT: 30 vehicles
General Description: Good low volume type facility
Geometry: Longer vertical and horizontal curves
Pavement: 20' pavement width; edge deterioration; no shoulder
Signing: Good warning and info
Marking: Centerline marking; no edge line
Safety: Good delineation of structures; good sight distance
General Comments: Comfortable speed at 55 mph, marked at 45 mph; white centerline strip along with yellow; two bridge structures -- adequate width; hazardous curves at 65 mph; tracking in middle of lane; ADT possibly higher

TAPE 1 - SECTION 4 - ARKANSAS

Location: SH 188, Northeast of Sweethome, Arkansas
Length: 6.0 miles
Classification: Unpaved State
ADT: 80 vehicles
General Description: One lane, low speed, gravel facility
Geometry: Sharp horizontal curves; long vertical curves; reasonable at low speeds
Pavement: 18' roadway width; fair maintenance; fairly smooth
Signing: Few info signs; no warning signs
Marking: None
Safety: Adequate sight distance at low speeds
General Comments: Two tracking on straightaways; three tracking on curves; comfortable speed at 35 mph; curve speed at 20 mph; one-lane bridge; two vehicles meeting, maneuvered easily

TAPE 2 - SECTION 5 - ARKANSAS

Location: SH 240 from Caddo Cap to Hopper, Arkansas
Length: 6.0 miles
Classification: Paved, marked State
ADT: 240 vehicles
General Description: Good medium speed facility; also good at night
Geometry: Long horizontal and vertical curves
Pavement: 20' pavement width; no shoulder; some type of surface treatment; grass on pavement edge
Signing: Some warning signs without speed; large route marking; "Litter" sign; city info signs
Marking: No delineation other than structures; good to poor markings
Safety: Good sight distance; structures are delineated
General Comments: Comfortable speed at 55 mph; good side slopes and ditches; better facility in regard to side road safety; curve warning signs 12" x 24", small confirmation signs; curve arrow signs serve as delineators; road section restrictive at west end, also less safe and reduced speed

TAPE 2 - SECTION 6 - ARKANSAS

Location: SH 240 from Caddo Gap to Hopper, Arkansas
Length: 1.0 mile
Classification: Paved, unmarked State
ADT: 240 vehicles
General Description: Good medium speed facility
Geometry: Good horizontal and vertical alignment
Pavement: 20' pavement width
Signing: Relatively new signs
Marking: None
Safety: Good sight distance
General Comments: Comfortable at 55 mph

TAPE 2 - SECTION 7 - ARKANSAS

Location: County Road #4 from Hopper to Albert Pike, Arkansas
Length: 6.0 miles
Classification: Unpaved County
ADT: 50 vehicles
General Description: Rural, low volume, gravel facility
Geometry: Fair horizontal and vertical alignment for low speed
Pavement: 16' roadway width; good maintenance; some sections of 12' width
Signing: Few info signs; no warning signs; "Livestock" sign
Marking: None
Safety: Sideroad terrain restrictive; fair sight distance
General Comments: Narrow bridge, no delineation; two tracking; comfortable speed at 30 mph; bad sections, washed, speed reduced to 20 mph; some three tracking; waterhole; two very narrow bridges

TAPE 3 - SECTION 8 - ARKANSAS

Location: U.S. Forest Road at Albert Pike, Arkansas
Length: 0.5 mile
Classification: Paved, unmarked Federal
ADT: 25 vehicles
General Description: Typical low volume, low speed forest road
Geometry: Mountainous terrain; many short verticals; sharp horizontals
Pavement: Deteriorated edges
Signing: Small "One Lane Bridge" sign
Marking: None
Safety: Some delineation on curves; restrictive topography
General Comments: Speed roughly 30 mph; three tracking on curves

TAPE 3 - SECTION 9 - ARKANSAS

Location: SH 369 from Albert Pike to Langley, Arkansas
Length: 3.0 miles
Classification: Paved, unmarked State
ADT: 100 vehicles
General Description: New facility with good design and construction
Geometry: Very good vertical and horizontal alignment
Pavement: 28' pavement width
Signing: Few info signs
Marking: None
Safety: Adequate sight distance
General Comments: Four tracking; road recently constructed

TAPE 3 - SECTION 10 - ARKANSAS

Location: County road #30 from Salem to SH 8
Length: 5.0 miles
Classification: Paved, unmarked County

TAPE 3 - SECTION 10 - ARKANSAS (cont.)

ADT: 60 vehicles
General Description: High-type County facility
Geometry: Good vertical and horizontal alignment; mountainous terrain
Pavement: 20' pavement width; about 4' rock shoulder; high-type pavement
Signing: Good to excellent warning signs; few info signs
Marking: None
Safety: Very good sight distance; good side slope and ditch maintenance
General Comments: full complement of info and warning sign; four tracking; average speed 45-55 mph; some roadside development; "Stop Ahead" warning sign, approximately 25"

TAPE 3 - SECTION 11 - ARKANSAS

Location: City-County road north of Glenwood, Arkansas
Length: 2.0 miles
Classification: Paved, unmarked County
ADT: 90 vehicles
General Description: Good County paved road for low speed and low volume
Geometry: Horizontal and vertical alignment; adequate for fairly low speeds
Pavement: 18' pavement width
Signing: No signs observed
Marking: None
Safety: Nonrestrictive terrain; fair roadside maintenance
General Comments: Three tracking; average speed 40 mph

TAPE 3 - SECTION 12 - ARKANSAS

Location: SH 240 from Hopper to Caddo Gap, Arkansas
Length: 1.0 mile
Classification: Paved, unmarked State
ADT: 240 vehicles
General Description: Good rural highway
Geometry: Adequate horizontal and vertical alignment
Pavement: 20' pavement width
Signing: Numerous warning signs
Marking: None
Safety: Fair
General Comments: Good facility; observed hearse

TAPE 4 - SECTION 13 - ARKANSAS

Location: U.S. Forest Service Road at Albert Pike, Arkansas
Length: 3.0 miles
Classification: Paved, unmarked Federal
ADT: 30 vehicles
General Description: Low speed forest road; mountainous terrain
Geometry: Adequate only at low speeds
Pavement: 16' roadway width

TAPE 4 - SECTION 13 - ARKANSAS (cont.)

Signing: Numerous info and warning signs; "Dangerous Curve: sign
Marking: None; delineators on curve edge
Safety: Sight distance restricted
General Comments: Two tracking; topography rough; one lane bridge; three-four tracking on curves; several operationally dangerous curves

TAPE 4 - SECTION 14 - ARKANSAS

Location: U.S. Forest Service Road between Albert Pike and Little Missouri Falls, Arkansas
Length: 6.0 miles
Classification: Unpaved Federal
ADT: 25 vehicles
General Description: Low speed winding forest road
Geometry: Horizontal alignment rough; vertical alignment adequate
Pavement: 14' roadway width; relatively smooth; some sections 12' wide
Signing: No warning signs; few info signs
Marking: None
Safety: Sight distance restrictions; rough topography and close in on roadway
General Comments: Two tracking throughout; comfortable speed at 25 mph; heavily traveled, ADT needs possible adjustments; one lane bridge -- no advance warning; speed commensurate to warning signs; very low speeds when meeting vehicles; no particular operational problems; no problems when passing; one lane bridge, very low speeds required

TAPE 5 - SECTION 1 - OKLAHOMA

Location: McCurtain County, Oklahoma
Length: 1.0 mile
Classification: Paved, unmarked County
ADT: 125 vehicles
General Description: Typical Oklahoma County road
Geometry: Generally good vertical and horizontal alignment
Pavement: 16' pavement width
Signing: Only two stop signs
Marking: None
Safety: Adequate sight distance; couple of hazardous, no warning curves
General Comments: Three tracking; railroad crossing sign on wrong sign - no advance warning; average speed 35-40 mph; passing speed at 24 mph

TAPE 5 - SECTION 2 - OKLAHOMA

Location: McCurtain County, Oklahoma
Length: 1.5 miles
Classification: Paved, unmarked County
ADT: 100 vehicles
General Description: Typical rural County road in Oklahoma; mostly local traffic

TAPE 5 - SECTION 2 - OKLAHOMA (cont.)

Geometry: Rough vertical alignment; adequate horizontal
Pavement: 14' pavement width
Signing: None
Marking: None
Safety: Adequate for low speeds, low volume
General Comments: Two tracking; average speed 25 mph; narrow bridge -- no advance warning

TAPE 5 - SECTION 3 - OKLAHOMA

Location: McCurtain County, Oklahoma
Length: 2.5 miles
Classification: Paved, unmarked County
ADT: 375 vehicles
General Description: Very high-type County road; serves large factory operation
Geometry: Good vertical and horizontal alignment
Pavement: 26' pavement width; rough surface caused by trucks; some maintenance problems
Signing: No warning signs; few delineators
Marking: None
Safety: Adequate
General Comments: Railroad grade crossing -- no advance warning; average speed at 40-45 mph; fiberboard plant; four tracking

TAPE 5 - SECTION 4 - OKLAHOMA

Location: McCurtain County, Oklahoma
Length: 1.5 miles
Classification: Paved, unmarked County road
ADT: 250 vehicles
General Description: Very good, safe County facility
Geometry: Long, straight horizontal tangents; rolling vertical alignment
Pavement: 22- pavement width
Signing: No warning signs
Marking: None
Safety: Sight distance adequate
General Comments: Three tracking; average speed at 50 mph

TAPE 5 - SECTION 5 - OKLAHOMA

Location: McCurtain County, Oklahoma
Length: 1.0 mile
Classification: Paved, unmarked County
ADT: 100 vehicles
General Description: Typical rural County road
Geometry: Both horizontal and vertical alignment rough
Pavement: 16' pavement width
Signing: No warning signs; uncontrolled rural intersections

TAPE 5 - SECTION 5 - OKLAHOMA (cont.)

Marking: None
Safety: Adequate sight distance; side road terrain restrictive
General Comments: Three tracking; average speed at 40 mph

TAPE 5 - SECTION 6 - OKLAHOMA

Location: McCurtain County, Oklahoma
Length: 2.5 miles
Classification: Paved, unmarked County
ADT: 200 vehicles
General Description: Good rural, County facility
Geometry: Good horizontal alignment; vertical alignment rough
Pavement: 22' pavement width
Signing: No warning or info sings; stop-controlled intersections
Marking: None
Safety: Adequate
General Comments: Three tracking; average speed at 45 mph; railroad grade crossing -- advance warning; passing maneuvers maintained easily

TAPE 5 - SECTION 7 - OKLAHOMA

Location: Choctaw County, Oklahoma
Length: 3.0 miles
Classification: Unpaved County
ADT: 75 vehicles
General Description: Rough, rural County road
Geometry: Horizontal alignment good; vertical alignment rolling and rough
Pavement: 14' pavement width
Signing: None
Marking: None
Safety: Adequate for low speed, low volume
General Comments: Average speed at 30-35 mph; ditches washed and rough; two tracking; bridge over turnpike; some three tracking on hills

TAPE 6 - SECTION 8 - OKLAHOMA

Location: SH 144 North of Antlers, Oklahoma
Length: 6.0 miles
Classification: Paved, marked State
ADT: 350-400 vehicles
General Description: Very good State highway facility
Geometry: Rolling to mountainous topography
Pavement: 32' pavement width; shoulder 5' in width; pavement surface varies
Signing: Adequate warning and info signs
Marking: Centerline, edgeline; delineation good
Safety: Excellent sight distance and roadside safety design
General Comments: Average speed 55-60 mph; wide, safe bridges

TAPE 6 - SECTION 9 - OKLAHOMA

Location: SH 144 North of Moyers, Oklahoma
Length: 6.0 miles
Classification: Unpaved State
ADT: 200 vehicles
General Description: Very poor State highway; however, signing and delineation good
Geometry: Curving horizontal alignment at times; adequate vertical alignment
Pavement: 16' roadway width; rough gravel surface; some sections at 12' width
Signing: Good warning and info signs; no regulatory signs
Marking: Very good delineation and structures and hazards
Safety: Side road terrain hazardous; poor signt distance at times
General Comments: Two tracking on straightaway; three tracking on curves and hills; average speed at 30 mph; low water crossing; "Unimproved Road" sign; one lane bridge, very poor

TAPE 6 - SECTION 10 - OKLAHOMA

Location: SH 144 outside of Noshoba, Oklahoma
Length: 0.5 mile
Classification: Unpaved State
ADT: 125 vehicles
General Description: Unpaved, unengineered, low quality State facility
Geometry: Adequate
Pavement: 22' roadway width
Signing: Very good warning sign system
Marking: Delineation of structures
Safety: No visible safety problems
General Comments: Three tracking; average speed 35 mph

TAPE 6 - SECTION 11 - OKLAHOMA

Location: SH 144 between US 271 and US 259
Length: 1.5 miles
Classification: Unpaved State
ADT: 275 vehicles
General Description: High-type unpaved facility; adequate for moderate speeds
Geometry: No problems either vertically or horizontally
Pavement: 30' pavement width
Signing: Good warning signs
Marking: Full delineation of structures
Safety: Very good facility; good sight distance
General Comments: Average speed of 45-50 mph; State confirmation signs; bridge across little river; four tracking

TAPE 7 - SECTION 11a (2nd Run) - OKLAHOMA

Location: SH 144 between US 271 and US 259
Length: 2.5 miles
Classification: Unpaved State
ADT: 275 vehicles
General Description: High-type unpaved facility
Geometry: Good vertical and horizontal alignment
Pavement: 30' roadway width
Signing: Good warning and info signs
Marking: Delineation of structures
Safety: Wide cross-section makes facility both safe and comfortable
General Comments: Four tracking throughout one section of five tracking; average speed 45-50 mph; bridge over little river, 28' wide; cross-section drops to 18' width last 0.5 miles; speed reduction to 30 mph; three tracking

TAPE 7 - SECTION 12 - OKLAHOMA

Location: Southwest of Cloudy, Oklahoma
Length: 3.0 miles
Classification: Unpaved County
ADT: 250 vehicles
General Description: Very good County road
Geometry: Adequate at low to moderate speeds
Pavement: 20' roadway width; sandy, gravel surface; good maintenance
Signing: No warning or regulatory signs
Marking: None
Safety: Good sight distance
General Comments: Three tracking; narrow bridge; "Load Limit" sign; average speed at 35-40 mph; no passing problems; some sections of two tracking

TAPE 7 - SECTION 13 - OKLAHOMA

Location: Southwest of Cloudy, Oklahoma
Length: 1.0 mile
Classification: Paved County
ADT: 250 vehicles
General Description: Typical paved County road with large truck traffic
Geometry: Adequate
Pavement: 20' pavement width; edge raveling
Signing: None
Marking: None
Safety: Fair; no delineation of structures
General Comments: Narrow bridge, one lane -- no advance warning; three tracking; average speed at 45 mph

TAPE 7 - SECTION 14 - OKLAHOMA

Location: Pushmataha County, Oklahoma
Length: 6.0 miles
Classification: Paved, marked county
ADT: 200 vehicles
General Description: Poorly constructed road under County maintenance
Geometry: Long horizontal tangents; slight vertical change
Pavement: 22' pavement width
Signing: No warning or info signs; uncontrolled rural intersections
Marking: Centerline not straight; weaving
Safety: Intersections hazardous; little delineation
General Comments: Average speed at 60 mph; comparable to lower class Texas FM

TAPE 7 - SECTION 15 - OKLAHOMA

Location: McCurtain County, Oklahoma
Length: 2.0 miles
Classification: Paved, unmarked County
ADT: 175 vehicles
General Description: Good paved road; however, hard to determine function
Geometry: Fair horizontal alighment; adequate vertical alignment
Pavement: 22' pavement width; good surface
Signing: None; uncontrolled rural intersections
Marking: None
Safety: Delineators knocked down; roadside safety design good
General Comments: "Ice on Bridge" warning sign; speed about 55 mph; reduced speed on curves; long tangent last 0.5 miles.

TAPE 8 - SECTION 16 - OKLAHOMA

Location: Forest Service Road 4212 near Haworth, Oklahoma
Length: 4.0 miles
Classification: Unpaved Federal
ADT: 125 vehicles
General Description: Typical unpaved forest road
Geometry: Long horizontal tangent section; slight vertical changes
Pavement: 14' roadway width; shale surface
Signing: None
Marking: None
Safety: Good roadside safety design
General Comments: Three tracking; speed between 35-45 mph; reduced speed in meeting cars; forest service info sign

TAPE 8 - SECTION 17 - OKLAHOMA

Location: Forest Service Road 9075, 9076 in Quachita National Forest
Length: 6.0 miles
Classification: Paved Federal

TAPE 8 - SECTION 17 - OKLAHOMA (Cont.)

ADT: 125 vehicles
General Description: Winding, restrictive forest road
Geometry: Vertical and horizontal alignment fair
Pavement: 20' pavement width; poorly maintained
Signing: None; stop-controlled intersections
Marking: None
Safety: Pavement condition hazardous
General Comments: Average speed 35-40 mph; three tracking; narrow bridge; "Slow" sign mounted two feet above pavement; narrow bridge--no advance warning; "Prevent Forest Fire" sign

TAPE 8 - SECTION 18 - OKLAHOMA

Location: Forest Service Road 211 between Moon and America, Oklahoma
Length: 2.0 miles
Classification: Unpaved Federal
ADT: 125 vehicles
General Description: Good unpaved forest road
Geometry: Adequate
Pavement: 20' roadway width; Gravel surface
Signing: None
Marking: None
Safety: Good sight distance
General Comments: Railroad parallels left side of road; three tracking

TAPE 8 - SECTION 19 - OKLAHOMA

Location: Forest Service Road 6113 near America, Oklahoma
Length: 1.0 mile
Classification: Unpaved Federal
ADT: 50 vehicles
General Description: Forest Service "Development" road
Geometry: Good horizontal alignment; vertical alignment relatively flat
Pavement: 10' roadway width; fairly smooth
Signing: None
Marking: None
Safety: R-O-W cleared back from road
General Comments: Average speed 30-35 mph; guardposts and stop sign at road intersection; definite crown and drainage

TAPE 9 - SECTION 1 - LOUISIANA

Location: USFS Road 565 from Readheimer to Ashland, Louisiana
Length: 4.4 miles
Classification: Paved, unmarked Federal
ADT: 150 vehicles
General Description: High-type rural facility
Geometry: Rolling terrain; good horizontal alignment

TAPE 9 - SECTION 1 - LOUISIANA (cont.)

Pavement: 20' pavement width; seal-coat type of treatment; edge deterioration; grass on edges
Signing: Good warning signs; no regulation or info signs; route markers
Marking: None
Safety: R-O-W cleared back from roadway
General Comments: Three tracking road; leads to lookout tower; forest service route marker; R-O-W cut back, clean; ADT about 150; 50 mph pretty comfortable speed; tracking on curves; some curves have warning, some don't; good roadway; concrete ditches; slab structures; some bad spots in road

TAPE 9 - SECTION 2 - LOUISIANA

Location: County road off of USFS Road 565 near Ashland, Louisiana
Length: 3.0 miles
Classification: Paved, unmarked County
ADT: 30 vehicles
General Description: Low speed, rural facility
Geometry: Vertical alignment fair; horizontal alignment poor
Pavement: 16' pavement width
Signing: No signs at all
Marking: None
Safety: Restricted sight distance throughout
General Comments: No signs and no markings; driving 35-40 mph; mainly two tracking; some three tracking on curves; never know what to expect; 20 mph around that curve; some sections reduced to 12'-14' width; pavement encourages speeds above that which alignment will allow

TAPE 9 - SECTION 3 - LOUISIANA

Location: USFS Road 525 near Ashland, Louisiana
Length: 2.7 miles
Classification: Unpaved, unmarked Federal
ADT: 30 vehicles
General Description: Engineered, low volume, low speed gravel road; rolling terrain
Geometry: Good vertical alignment; fair horizontal alignment
Pavement: Variable 10'-14'; gravel surface; smooth surface
Signing: None
Marking: None
Safety: Delineation on culverts; cleared R-O-W increases sight distance
General Comments: Two tracking throughout; ADT less than 30; well-engineered; reflectors marking location of culverts; 14' bridge structure; driving around 30 mph; tangents around 35-40 mph; seems to be no need for warning

TAPE 9 - SECTION 4 - LOUISIANA

Location: SH 126 East of Readheimer, Louisiana
Length: 2.5 miles
Classification: Paved, marked State
ADT: 200 vehicles
General Description: Narrow State highway; otherwise, well-engineered
Geometry: Rolling vertical alignment; good horizontal alignment
Pavement: 18' pavement width
Signing: Good warning; route marker
Marking: Marked but wiped out because of tracking
Safety: Excellent sight distance throughout; cleared R-O-W
General Comments: Driving 50 mph; not sure how people stay in lanes; three tracking; tracking right over center stripe; Louisiana green on white route marker; three tracking around curve; good sight distance pickup went on grass; problems meeting car at night; long tangent section

TAPE 9 - SECTION 5 - LOUISIANA

Location: USFS "8-mile creek road" off of SH 126
Length: 1.0 mile
Classification: Unpaved, unmarked Federal
ADT: 30 vehicles
General Description: Unique forest service road
Geometry: Good vertical alignment; fair horizontal alignment
Pavement: 20' pavement width; unknown surface--possibly lime-stabilized sand
Signing: None
Marking: None
Safety: Reasonably safe
General Comments: New road; definitely stabilized; new forest service bridge; R-O-W cleared; ditches formed; pretty sharp curve -- not as natural as engineered road

TAPE 10 - SECTION 6 - LOUISIANA

Location: SH 126 East of Readheimer, Louisiana
Length 4.0 miles
Classification: Paved, marked State
ADT: 200 vehicles
General Description: Good facility except for pavement quality
Geometry: Good horizontal and vertical alignment
Pavement: 18' pavement width
Signing: Good warning and info signing
Marking: Striped, but obliterated
Safety: Sight distance good; R-O-W clear; good side slopes
General Comments: Three tracking; difficult to stay in lane; driving at 45 mph; bad sections on pavement; end of section has restricted R-O-W

TAPE 10 - SECTION 7 - LOUISIANA

Location: SH 501 South of Mill, Louisiana
Length: 6.2 miles
Classification: Paved, unmarked State
ADT: 200 vehicles
General Description: Facility has good alignment, marking and sight distance
Geometry: Rolling topography; long tangents connected by moderate degree curves
Pavement: 18' pavement width; rough in spots; pavement bleeding
Signing: Full complement of warning signs; some info sings
Marking: None
Safety: Delineation on structures--slash bars; R-O-W mostly clear; good sight distance
General Comments: Good intersection approach signing; Federal aid secondary road; no centerline; definite three tracking; bridge structure--full width; mile-post marker; slightly rough pavement measured structure width; just move over when meeting car; saw only one posted regulatory sign; advisory signs; engineered for good sight distance; driving 55 mph; coming up on curve and intersection; bridge on curve with two tracking; otherwise, three tracking

TAPE 10 - SECTION 8 - LOUISIANA

Location: USFS Road 565 East of Goldonna, Louisiana
Length: 2.0 miles
Classification: Paved, unmarked Federal
ADT: 40 vehicles
General Description: Narrow roadway; adequate only at moderate speeds
Geometry: Mostly good horizontal and vertical alignment
Pavement: 16' pavement width; tight 16'; edges in good shape
Signing: None
Marking: None
Safety: Good sight distance; R-O-W fairly clear; delineation on structures
General Comments: Meeting a car; camera problems; cattleguards on both sides of church; long tangent; 45 mph; no warning signs and no marking; limited R-O-W; sharp curve; meeting car: both get on edges; meeting truck: both went off edges; coming up to 20' bridge; driving 45 mph; edges in good shape

TAPE 10 - SECTION 9 - LOUISIANA
(Bad Picture--No Visual Analysis)

Location: USFS Road 502, South of Mill, Louisiana
Length: 2.0 miles
Classification: Unpaved, unmarked Federal
ADT: 30 vehicles
General Description: Lower class forest service road

TAPE 10 - SECTION 9 - LOUISIANA (cont.)

Geometry: Fair
Pavement: 14' pavement width; all-weather gravel
Signing: No warning signs
Marking: None
Safety: Safe at low speeds
General Comments: Two tracking; speed 30 mph -- about maximum speed

TAPE 11 - SECTION 10 - LOUISIANA
(Bad Picture--No Visual Analysis)

Location: USFS Road 502, South of Mill, Louisiana
Length: 1.6 miles
Classification: Unpaved, unmarked Federal
ADT: 30 vehicles
General Description: Fairly good forest service road
Geometry: Adequate at low speeds
Pavement: 12'-14' pavement width
Signing: None
Marking: None
Safety: Safe at low speeds
General Comments: Vague Y-intersection; no problems; speed 30-35 mph; warning signs would serve no function; at low speeds, plenty of response time; direct correlation between pavement roughness and sight distance; intersection with stop sign

TAPE 11 - SECTION 11 - LOUISIANA
(Bad Picture--No Visual Analysis)

Location: County road off of SH 91 near Black Lake area, Louisiana
Length: 3.3 miles
Classification: Paved, unmarked County
ADT: 300 vehicles
General Description: High use recreation road
Geometry: Alignment fairly severe with unexpected changes
Pavement: 16'-18' pavement width
Signing: None
Marking: None
Safety: Safe <u>only</u> at low speeds
General Comments: Unexpected and unknown on County road; need for more consistent shoulder; centerline would be of no use; goes down into camp area; advertising signs; speed 25 mph on curves; pavement encourages higher speed than alignment will sustain: characteristic of County road; alignment unengineered

TAPE 11 - SECTION 12 - LOUISIANA
(Bad Picture--No Visual Analysis)

Location: County road near Black Lake area, Louisiana
Length: 6.0 miles

TAPE 11 - SECTION 12 - LOUISIANA (cont.)

Classification: Unpaved, unmarked County
ADT: 50 vehicles
General Description: Typical unpaved lower class County road
Geometry: Winding, curving horizontal alignment
Pavement: 14' pavement width; variable with rough spots
Signing: No warning signs
Marking: None
Safety: Adequate at low speeds
General Comments: Driving 35 mph; three tracking on curves; mudhole; mail route; hard to tell function of road; could not sign every curve; unfeasible; too many curves; driving little too fast; 40 mph too fast; primary two tracking; rough spots; lose sight distance along with speed; provides safety factor; great difference with respect to pavement width whether engineered or non-engineered; speed 30-35 mph; road little tricky; intersection with stop control

TAPE 11 - SECTION 13 - LOUISIANA
(Bad Picture--No Visual Analysis)

Location: SH 1238 Southeast of Sikes, Louisiana
Length: 5.5 miles
Classification: Unpaved, unmarked State
ADT: 40 vehicles
General Description: Only unpaved State road in parish
Geometry: Adequate
Pavement: 18' pavement width
Signing: Occasional warning signs on sharper curves
Marking: None
Safety: Adequate
General Comments: Strictly two tracking; speed 40 mph; stop-controlled intersection; some sections have possibly been reconstructed; two tracking because of low volume; sharp crown

TAPE 12 - SECTION 13 - LOUISIANA
(Bad Picture--No Visual Analysis)

Location: SH 1238 Southeast of Sikes, Louisiana
Length: 5.5 miles
Classification: Unpaved, unmarked State
ADT: 40 vehicles
General Description: Only unpaved State road in parish
Geometry: Fair
Pavement: 18' pavement width; some 20' section one foot crown
Signing: Occasional warning signs on sharper curves
Marking: None
Safety: Adequate at low speeds
General Comments: Crown causes two tracking; no traffic at all; driving 40 mph which is too fast; "State Maintenance Ends" sign; bad spot in road; reverse curve sign; no particular difficulty; R-O-W clear on one side; tracking shift to clear side; slight three tracking on hill; intersection: full signing

TAPE 12 - SECTION 14 - LOUISIANA
(Bad Picture--No Visual Analysis)

Location: SH 127 Southeast of Sikes, Louisiana
Length: 6.0 miles
Classification: Paved, marked State
ADT: 75 vehicles
General Description: Very poor State road
Geometry: Rough profile
Pavement: 20' pavement width; bad areas on outer edge; rough road
Signing: Full complement of warning signs
Marking: Centerline, no passing
Safety: Pavement condition limits speed
General Comments: Narrow bridge; narrow 20' section; another narrow bridge; no outside curve delineation; driving 40-45 mph; another narrow bridge; road maintenance and alignment control speed; four tracking; bridges 18'-19' width; subtle difference between 18' and 20' width; rough pavement: completely torn up; a lot of narrow bridges; very short; route marker; lost ability to stay in lane; only warning needed is for surface

TAPE 12 - SECTION 15 - LOUISIANA
(Bad Picture--No Visual Analysis)

Location: SH 126 West of Sikes, Louisiana
Length: Approximately 2.0 miles
Classification: Paved, marked State
ADT: 400 vehicles
General Description: Lower class State paved road
Geometry: Rough
Pavement: 18' pavement width
Signing: Full complement of warning signs
Marking: Centerline obliterated from tracking
Safety: Adequate
General Comments: Three tracking across centerline; centerline obliterated; running speed 40-50 mph; can't get four tracking on 18' width; three tracking on hill

TAPE 12 - SECTION 16 - LOUISIANA
(Bad Picture--No Visual Analysis)

Location: SH 126 West of Dodson, Louisiana
Length: 2.0 miles
Classification: Paved, marked State
ADT: 200 vehicles
General Description: Poorly maintained State road
Geometry: Rough
Pavement: 19' pavement width; rough pavement
Signing: Full complement of warning signs
Marking: Centerline partially visible
Safety: Adequate

TAPE 12 - SECTION 16 - LOUISIANA (cont.)

General Comments: Four tracking on tangents, three tracking on curves; breakpoint between 18'-20'; bridge width 18'; bad section of pavement; single lane line; cattleguard; four tracking; restriped recently

TAPE 13 - SECTION 1 - TEXAS

Location: County road in Robertson County, East of FM 46
Length: 2.3 miles
Classification: Unpaved County
ADT: 25 vehicles
General Description: Narrow, low speed, unpaved County road
Geometry: Sharp, low speed curves between long tangents; vertically level
Pavement: 14' roadway width; red clay; fairly rough surface
Signing: None; church guide sign; stop sign at FM 46
Marking: None
Safety: R-O-W restrictive; no bridge marking; never less than 3.0 seconds reaction time on curves; sight distance poor on curves
General Comments: Two tracking; red clay dirt road; 15 mph curve; speed around 25 mph; unpredictable; small bridge; no markings; speed up to 35 mph; few houses; Y-intersection; ADT of 25 vpd; church guide sign; no particular need for warning; probability of conflict low; overhanging trees; R-O-W restriction and surface keep speed down; another 15 mph curve; difficult to pass; coming upon intersection with FM 46; stop sign

TAPE 13 - SECTION 2 - TEXAS

Location: FM 46 from Franklin to Wheelock, Texas
Length: 6.0 miles
Classification: Paved, marked State
ADT: 300 vehicles
General Description: Good, moderate speed facility
Geometry: Both horizontal and vertical alignment good
Pavement: 18' roadway width; slightly rough; limestone surface
Signing: Full complement of warning and information signs
Marking: Centerline and no passing
Safety: Delineators on all culverts; slash bars and delineators at bridge; excellent distance
General Comments: 50 mph curve warning sign; 55 mph road; room for four tracking, yet three tracking; bridge; went into 20' section on curve; edge of roadway well maintained; some edge wear on curves; several curve warning with no advisory speed; driving on centerline; little bumpy; wide R-O-W; no sight distance problems; no traffic; bridge with full hazard warning--40 mph advisory; driving 50 mph

TAPE 13 - SECTION 3 - TEXAS

Location: FM 2766 from Wixen, Texas to FM 974
Length: 3.0 miles
Classification: Paved, unmarked State
ADT: 100 vehicles
General Description: Fairly good FM road
Geometry: Slightly rolling, curving alignment
Pavement: 20' roadway width
Signing: Full complement of warning and information signs
Marking: None
Safety: Delineators and slash bars on large culverts; wide, clear R-O-W; sight distance good
General Comments: Driving 50 mph appears to be four tracking; following VW; no problems; treatment coming up to FM intersection; stop sign

TAPE 13 - SECTION 4 - TEXAS

Location: County road from FM 974 to OSR
Length: 3.2 miles
Classification: Paved, unmarked County
ADT: 75 vehicles
General Description: Well-aligned County road; induces higher speed than safe
Geometry: Excellent vertical and horizontal alignment
Pavement: 16' pavement width; slightly rough
Signing: None
Marking: None
Safety: Delineators at culverts
General Comments: Driving 45 mph; several narrow, unguarded bridge structures; delineators on metal and wood posts; relatively straight; two tracking; short bridges most critical element of road; alignment induces higher speed than safe; 45 mph little fast; undersigned; road too narrow for running speed

TAPE 14 - SECTION 5 - TEXAS

Location: FM 3058 between Caldwell and Tunis, Texas
Length: 3.5 miles
Classification: Paved, unmarked State
ADT: 250 vehicles
General Description: High speed, good operation facility
Geometry: Very good vertical and horizontal alignment
Pavement: 18' roadway width; smooth
Signing: Full complement
Marking: None
Safety: Delineators on all curves; excellent sight distance; R-O-W clear
General Comments: Well-designed road; good sight distance; full complement of signs and delineation; driving 55 mph; no problems; good smooth road; delineation on both sides of curve

TAPE 14 - SECTION 6 - TEXAS

Location: County road off FM 3058 near Caldwell, Texas
Length: 1.1 miles
Classification: Unpaved County
ADT: 50 vehicles
General Description: Typical unpaved Country road with better alignment
Geometry: Good vertical alignment; fairly level; few sharp curves
Pavement: 16' pavement width; variable
Signing: None
Marking: None
Safety: Fairly good sight distance; R-O-W mostly clear
General Comments: Curve came up unexpected; smoothness of surface caused speed to become too high

TAPE 14 - SECTION 7 - TEXAS

Location: County road between FM 3058 and FM 166
Length: 2.0 miles
Classification: Paved, unmarked County
ADT: 25 vehicles
General Description: Narrow, paved road; moderate speeds
Geometry: Fairly good vertical and horizontal alignment; some bad curves
Pavement: 14' roadway width
Signing: None; stop sign at intersection
Marking: None
Safety: Mostly clear sight distance; R-O-W mostly clear
General Comments: Three tracking; fairly straight road; driving 50 mph pavement encourages higher speed than safe; two tracking; visibility problems on curves; driving 55 mph; unexpected elements; stop sign; intersection with FM road

TAPE 14 - SECTION 8 - TEXAS

Location: U.S. Forest Service Road #216 in Sam Houston National Forest
Length: 2.7 miles
Classification: Paved, marked Federal
ADT: 100 vehicles
General Description: High-type, paved Federal road.
Geometry: Adequate vertical and horizontal alignment
Pavement: 18' roadway width
Singing: Couple road info signs; Sam Houston National Forest sign
Marking: Single yellow centerling; very recently striped
Safety: Fair sight distance
General Comments: Driving 40 mph, little rough; slowed down to 30 mph on curve; back up to 45 mph; now up to 50 mph; yellow stripe keeps you on your side; undecided about passing; relatively good road; have not crossed centerline once

TAPE - 14 - SECTION 9 - TEXAS

Location: U. S. Forest Service Road #208-216 in Sam Houston National Forest
Length: 2.0 miles
Classification: Unpaved Federal
ADT: 25 vehicles
General Description: Low speed, low volume, unpaved Forest road
Geometry: Good horizontal and vertical alignment
Pavement: 12' roadway width, sandy, rough
Signing: None; couple route markers
Marking: None
Safety: R-O-W restrictive
General Comments: Speed about 30 mph; no need for any information other than road itself; ADT sure low; coming into intersection with FS #216

TAPE 14 - SECTION 10 - TEXAS

Location: U.S. Forest Service Road #204
Length: 2.0 miles
Classification: Unpaved Federal
ADT: 50 vehicles
General Description: Very good low speed facility
Geometry: Good vertical and horizontal
Pavement: 16' roadway width; gravel surface
Signing: None; Stop sign at intersection
Marking: None
Safety: R-O-W restrictive
General Comments: Both two tracking and three tracking; some rough spots; driving 35 mph; four seconds of visibility on hill; plenty of time; up to 40 mph; stop sign at intersection

TAPE 14 - SECTION 11 - TEXAS

Location: FM 1375 in Sam Houston National Forest
Length: 1.5 miles
Classification: Paved, unmarked State
ADT: 125 vehicles
General Description: Good moderate speed farm-to-market
Geometry: Adequate horizontal and vertical alignment
Pavement: 18' roadway width; recent seal coat
Signing: Full complement
Marking: None
Safety: Good
General Comments: (Audio and Video trouble)

TAPE 15 - SECTION 12 - TEXAS

Location: FM 149 near Richards, Texas
Length: 3.2 miles
Classification: Paved, marked State
ADT: 200 vehicles

TAPE 15 - SECTION 12 - TEXAS (cont.)

General Description: Typical FM in rough terrain; adequate
Geometry: Horizontal alignment rough; vertical alignment rolling
Pavement: 18' roadway width
Signing: Full complement of signs
Marking: Double yellow centerline
Safety: Fair sight distance; R-O-W restrictive
General Comments: Speed 55 mph; curve advisory; 45 mph on curves; crooked little road, yet, drives pretty well

TAPE 15 - SECTION 13 - TEXAS

Location: FM 1486 from Richards to Shiro, Texas
Length: 2.5 miles
Classification: Paved, unmarked State
ADT: 250 vehicles
General Description: Good low volume State facility
Geometry: Very good
Pavement: 18' roadway width
Signing: Few signs; "Ice on Bridge - Drive Friendly."
Marking: None
Safety: Good sight distance; R-O-W clear; curve and culvert delineation
General Comments: Four distinct tracks; straight section; driving 55 mph; now three tracking; stop-controlled intersection; road widens slightly in curves; no problems

TAPE 15 - SECTION 14 - TEXAS

Location: County road in Brazos County, Texas
Length: 1.5 miles
Classification: Paved, unmarked County
ADT: 75 vehicles
General Description: Very good County road
Geometry: Adequate for moderate speeds
Pavement: 14' roadway width
Signing: Full complement of warning signs
Marking: None
Safety: Good sight distance; R-O-W clear
General Comments: Driving 30 mph in curve; basically one-lane road; driving 45 mph; pretty nice county road; almost three tracking on hill; coming up to intersection

TAPE 15 - SECTION 15 - TEXAS

Location: FM 219 in Erath County, Texas
Length: 4.0 miles
Classification: Paved, marked-unmarked State
ADT: 250 vehicles
General Description: Good FM facility for moderate speeds
Geometry: Good horizontal alignment in rolling terrain

TAPE 15 - SECTION 16 - TEXAS (cont.)

Pavement: 20' roadway width
Signing: Full complement of all signs
Marking: Centerline, no passing
Safety: Delineation on curve. R-O-W clear; good sight distance
General Comments: Following vehicle; driving 60 mph; curve warning signs; pretty sharp curve

TAPE 15 - SECTION 17 - TEXAS

Location: County road of FM 3025 near Huckaby, Texas
Length: 2.3 miles
Classification: Unpaved County
ADT: 50 vehicles
General Description: Rough aligned County road
Geometry: Fairly severe horizontal alignment in rolling topography
Pavement: 14'-16' roadway width; road surface smooth; caliche
Signing: None
Marking: None
Safety: R-O-W mostly clear; fairly adequate visibility
General Comments: Driving 45 mph with difficulty; sharp, hazardous curve; narrow bridge; two tracking; stop sign at intersection hidden

TAPE 15 - SECTION 18 - TEXAS

Location: County road in Erath County, Texas
Length: 4.0 miles
Classification: Unpaved County
ADT: 25 vehicles
General Description: Very low volume, low speed facility
Geometry: Long tangents connected by sharp curves
Pavement: 14' roadway width
Signing: None
Marking: None
Safety: R-O-W restrictive; fairly good sight distance
General Comments: Fairly good road; two tracking; 35 mph

TAPE 16 - SECTION 18 - TEXAS (cont.)

Location: County road in Erath County, Texas
Length: 4.0 miles
Classification: Unpaved County
ADT: 25 vehicles
General Description: Very low volume, low speed facility
Geometry: Long tangents connected by sharp curves
Pavement: 14' roadway width; fairly smooth
Signing: None
Marking: None
Safety: R-O-W restrictive; fairly good sight distance

TAPE 16 - SECTION 18 - TEXAS (cont.)

General Comments: Two tracking; 35 mph; much brush along road, sometimes one side, sometimes; narrow culvert; no problems; driving 40 mph; two tracking up hill; adequate sight distance; still 14' wide; brush extends into road; tree hit car; little narrow bridge; no protection; three tracking in this section; R-O-W clear now; T-intersection

TAPE 16 - SECTION 19 - TEXAS

Location: County road between Huckaby and Liberty, Texas
Length: 4.0 miles
Classification: Unpaved County
ADT: 50 vehicles
General Description: Fairly good County road for low speeds
Geometry: Slightly rough; rolling terrain; alignment bad
Pavement: 12'-14' roadway width; recently graded
Signing: None
Marking: None
Safety: R-O-W restrictive; sight distance mostly good except on curves
General Comments: Speed 16 mph on curve; little sight distance on side; lot of growth; speed 35 mph; good intersection; might need some warning on curves; bad curve; bridge coming up; some three tracking; speed 22 mph

TAPE 16 - SECTION 20 - TEXAS

Location: FM 1715 near Liberty, Texas
Length: 5.5 miles
Classification: Paved, marked State
ADT: 300 vehicles
General Description: Typical Texas FM in rolling terrain
Geometry: Long tangents; fairly sharp curves; hilly
Pavement: 18' roadway width; different colored pavements
Signing: Full complement of signs
Marking: Centerline and no passing
Safety: Delineation on Curves R-O-W clear; sight distance good
General Comments: Speed 45 mph; intersecting roads have no stop control; narrow 18'; wide bridge 22'; good R-O-W; Speed 55 mph; no passing

TAPE 17 - SECTION 21 - TEXAS

Location: County road from Mt. Zion Baptist Church to Morgan's Mill, Texas
Length: 4.0 miles
Classification: Paved, unmarked County
ADT: 125 vehicles
General Description: Extremely low volume County road
Geometry: Very good alignment for County road
Pavement: 16' roadway width; fairly rough

TAPE 17 - SECTION 21 - TEXAS (cont.)

SIGNING: None
Marking: None
Safety: Mostly clear R-O-W; sight distance fairly good
General Comments: Speed 35-45 mph; no control on side intersections; meeting car; no problems; bridge; two tracking; driving 45 mph; another bridge; three tracking over hill; speed 50 mph; good clear width of road; 10' wide narrow bridge; coming into Morgan's Mill; no stop control on side intersection

TAPE 17 - SECTION 22 - TEXAS

Location: FM 1188-1189 from Morgan's Mill to Bluff Dale, Texas
Length: 2.0 miles
Classification: Paved, marked State
ADT: 250 vehicles
General Description: Good FM facility
Geometry: Fair alignment
Pavement: 20' roadway width
Signing: Full complement of signs
Marking: Centerline offset
Safety: Delineation on curves and culverts; good sight distance; R-O-W clear
General Comments: Driving 45 mph; 20' bridge

TAPE 17 - SECTION 23 - TEXAS

Location: FM 1188 from Morgan's Mill to Bluff Dale, Texas
Length: 4.1 miles
Classification: Paved, marked State
ADT: 275 vehicles
General Description: Curving, rolling, low volume FM
Geometry: Alignment rough over rolling topography
Pavement: 18' roadway width; dark pavement
Signing Full complement of signs
Marking: Centerline and no passing striping
Safety: Curve and culvert delineation; R-O-W clear
General Comments: 45 mph curve warning; narrow, weak, load-limited bridge; orange-yellow striping; driving 55 mph; curve warning; cattle crossing sign; yield sign on side intersection; many curves and warning signs

TAPE 17 - SECTION 24 - TEXAS

Location: FM 1188 from Morgan's Mill to Bluff Dale, Texas
Length: 1.0 mile
Classification: Paved, marked State
ADT: 275 vehicles
General Description: Good, safe RR, curve, and bridge treatment
Geometry: Fairly good alignment
Pavement: 20' roadway width

TAPE 17 - SECTION 24 - TEXAS (cont.)

Signing: Full complement of signs
Marking: Centerline, no passing, RR warning
Safety: R-O-W clear; fair sight distance
General Comments: RR grade crossing treatment with curve; RR on 90^{o} curve; flasher; pavement message; no stop at intersection; going across narrow bridge

TAPE 17 - SECTION 25 - TEXAS

Location: County road from Bluff Dale to Camp Paluxy, Texas
Length: 4.1 miles
Classification: Unpaved County
ADT: 50 vehicles
General Description: Winding, curving, narrow County road
Geometry: Alignment rough and rolling
Pavement: 14' roadway width; fairly smooth
Signing: None
Marking: None
Safety: R-O-W fairly restrictive
General Comments: Green-white signs for homes, driveways; two tracking; narrow bridge; speed 45 mph

TAPE 18 - SECTION 26 - TEXAS

Location: County road near Stephenville, Texas
Length: 4.4 miles
Classification: Unpaved County
ADT: 75 vehicles
General Description: Good County road, considering topography
Geometry: Fairly good alignment through rugged, hilly terrain
Pavement: 16' pavement width; smooth road
Signing: None
Marking: None
Safety: R-O-W restrictive; sight distance adequate; red delineators
General Comments: 35 mph; attempt at narrow bridge marking; 45 mph; over 3 seconds sight distance; three tracking

TAPE 18 - SECTION 27 - TEXAS

Location: County road from Bowman to Ridge Chappel, Texas
Length: 4.0 miles
Classification: Unpaved County
ADT: 50 vehicles
General Description: Fairly good County road
Geometry: Good alignment for rolling terrain
Pavement: 16' roadway width, smooth
Signing: None
Marking: None

TAPE 18 - SECTION 28 - TEXAS

Signing: None
Marking: None
Safety: Restricted R-O-W; sight distance limited on curves
General Comments: 12 mph curve; speed normally 30 mph; two tracking; Jigsaw curves; no control on side intersections; no control needed; 20 mph curve; 35-40 mph; roadbed, uncertain; narrow bridge

TAPE 19 - SECTION 29 - TEXAS
(Video Trouble)

Location: FM 914 near Alexander, Texas
Length: 5.0 miles
Classification: Paved, marked State
ADT: 300 vehicles
General Description: Good FM facility
Geometry: Fairly good alignment over rolling topography
Pavement: 20' roadway width
Signing: Full complement of signing and marking
Marking: Centerline, no passing
Safety: R-O-W clear; sight distance good; delineation on curves
General Comments: Driving 55 mph; open country; 50 mph warning; 90^o curve; only problems are little curves coming out of tangents; need for warning; all-weather shoulders; coming into speed zone; county road, stop controlled; intersection; driving through

TAPE 19 - SECTION 30 - TEXAS

Location: FM 1950 from Sego to Chilton, Texas
Length: 5.5 miles
Classification: Paved, unmarked State
ADT: 300 vehicles
General Description: Lower type quality FM road
Geometry: Fairly straight; few curves
Pavement: 16' roadway width
Signing: Full complement of signs
Marking: None
Safety: R-O-W clear; good sight distance; culvert delineation; no curve delineation
General Comments: Three tracking; 18' load-zoned bridge; speed 45 mph; another load-zoned bridge coming up; meeting vehicle; both cars right on edge; fair curve; speed 50 mph; culvert delineation; marked and widened at intersection

APPENDIX B

DATA REDUCTION AND ANALYSIS
RURAL SIGNING AND MARKING

Tapes________________

Sections______________

State________________

Test Section______________

Film Count________________

Time______________________

Location____

____

ADT____

Classification____

Film Count______________

Time____________________

Driving Function Constants

Roadway Type

Paved __________

Unpaved __________

Marked __________

Unmarked__________

County __________

Federal __________

State __________

Roadway Cross-Section

Width 10'-14' __________

Width 14'-18' __________

Width 18'-22' __________

Width 22'-26' __________

Width 26'-30' __________

Paved Shoulder __________

Unpaved Shoulder __________

No Shoulder __________

Ditch and Side-Slopes __________

Ditch __________

No Ditch __________

Roadway Geometrics

Straight and Level __________

Straight Upgrade __________

Straight Downgrade __________

Curve Level __________

Curve Upgrade __________

Curve Downgrade __________

Operating Speed

0-10 ____________

10-25 ____________

25-40 ____________

40-55 ____________

Over 55 ____________

R-O-W

Cleared ____________

Restrictive ____________

Hazardous ____________

Driving Function Inputs

Sign Observation

Information ____

Film Count ____________ Time ____________

Regulation ____

Film Count ____________ Time ____________

Warning ____

Film Count ____________ Time ____________

Directional ____

Film Count ____________ Time ____________

Prohibitive ____

Film Count ____________ Time ____________

Roadway Marking Observation

Centerline ____

Film Count ____________ Time ____________

Edgeline ____

Film Count ____________ Time ____________

No-Passing Zone ____

Film Count ____________ Time ____________

Delineation Observation

Post ____________________

Film Count __________ Time __________

Hazard Warning ____________________

Film Count __________ Time __________

Structure Warning ____________________

Film Count __________ Time __________

Lateral Alignment

Center of Roadway ____________________

Film Count __________ Time __________

Right Side Roadway ____________________

Film Count __________ Time __________

Left Side Roadway ____________________

Film Count __________ Time __________

Traffic Observation

Meeting Vehicle ____________________

Film Count __________ Time __________

Following Vehicle ____________________

Film Count __________ Time __________

Passing Vehicle ____________________

Film Count __________ Time __________

Sight Distance Observation

Good ____________________

Film Count __________ Time __________

Adequate ____________________

Film Count __________ Time __________

Restricted ____________________

Film Count __________ Time __________

Surface Condition Observation

Rough ______________________________

Film Count __________ Time __________

Smooth ______________________________

Film Count __________ Time __________

Holes ______________________________

Film Count __________ Time __________

Washed Out ______________________________

Film Count __________ Time __________

Water Crossing ______________________________

Film Count __________ Time __________

Sturcture Observation

Bridge (Wide) ______________________________

Film Count __________ Time __________

Bridge (One-Lane) ______________________________

Film Count __________ Time __________

Bridge (Narrow) ______________________________

Film Count __________ Time __________

Culvert ______________________________

Film Count __________ Time __________

Condition ______________________________

Film Count __________ Time __________

Other Observations

____

Film Count __________ Time __________

____

Film Count __________ Time __________

____

Film Count __________ Time __________

Driving Function Outputs
Situation ____________________

____

____

____

Responses

____

Film Count __________ Time __________

____

Film Count __________ Time __________

____

Film Count __________ Time __________

Driver Verbal Observations

____

____

____

____

____

Evaluation*

____

____

____

____

____

Conclusion*

____

____

____

____

____

---

*Evaluation and conclusion based on following considerations:

1. Information needed is not displayed
2. Information needed is inadequate or incomplete
3. Information given is in error or misleading
4. Information given is confusing or ambiguous
5. Information given is not in needed location; out of place; not enough processing and reaction time is allowed
6. Information given is inadequate because of environmental or physical factors
7. Is the information given warranted for the safe operation of the facility?

Test site studies were conducted under daytime, fair weather conditions. Evaluations and conclusions were also formulated on this basis. Therefore, final design recommendations must consider night time, adverse weather factors to be feasibly safe.

APPENDIX C

(OMB 04-S75029)

SIGNS AND MARKINGS FOR LOW VOLUME RURAL ROADS
QUESTIONNAIRE

1. Which of the following pavement markings indicate that passing is prohibited by any vehicle traveling in any direction? (Choose all appropriate answers)

a. b. c. d. e. f. g.

2. Which of the following pavement markings define the centerline of the roadway and indicate that passing is allowed from at least one direction of travel? (Choose all appropriate answers)

a. b. c. d. e. f. g.

3. Is there a difference in meaning between these pavement markings? (Check correct answer)

a. b.

Yes _____

No _____

(OMB 04-S75029)

4. Is there a difference in meaning between these pavement markings? (Check correct answer)

a.

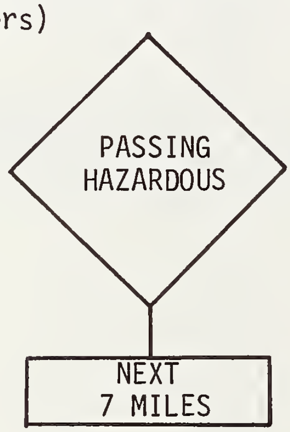
b.

Yes _____

No _____

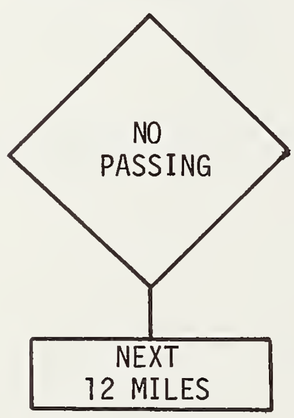
5. Which of the following signs indicate that passing may be undertaken with caution on this roadway? (Circle all appropriate answers)

a.



b.

c.

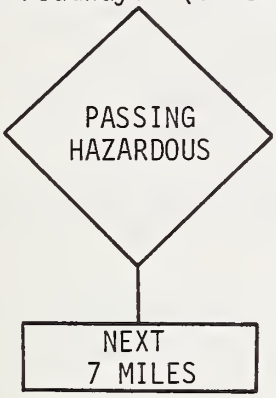


d.

(OMB 04-S75029)

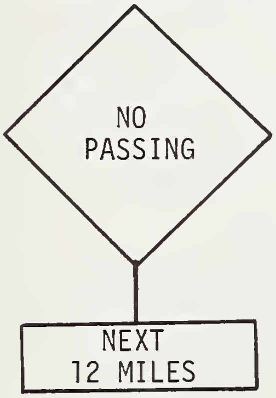
6. Which of the following signs indicate that passing is prohibited on this roadway? (Circle all appropriate answers)

a.



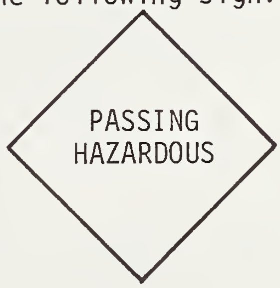
b.

c.



d.

7. What is the meaning of the following sign? (Circle the best answer)



a. Passing on this roadway should be avoided due to conditions.
b. Passing opportunities are limited and may be taken at risk.
c. Passing is allowed, only with extreme caution.
d. Passing is prohibited in both directions of travel.

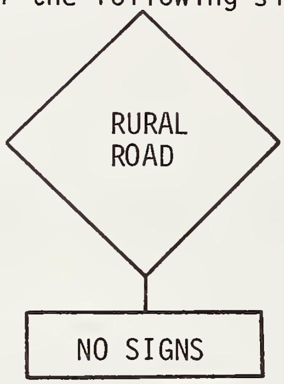
8. Do you, as a driver, prefer a sign or pavement marking to indicate "No Passing?"

Sign _____ Marking _____

9. If you were following a car on this roadway, would passing warning be necessary?

a. Yes _____ No _____
b. Yes _____ No _____
c. Yes _____ No _____
d. Yes _____ No _____

10. What is the meaning of the following sign? (Circle the best answer)



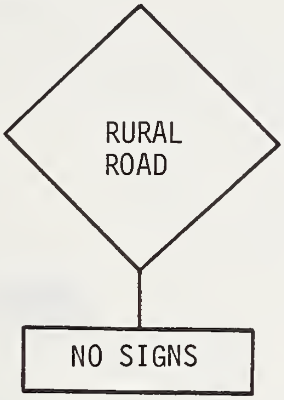
a. This type of road never has any signs.
b. Farms and animals are found along the road ahead.
c. No signs are needed along this road.
d. This roadway is a country road; therefore, no warning will be provided at potentially hazardous locations.

11. What is the meaning of the following sign? (Circle the best answer)

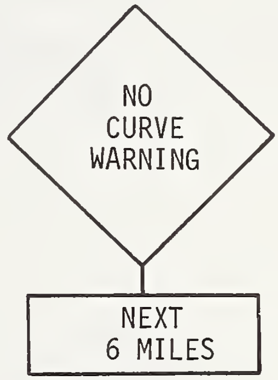
a. A road named "Winding Road" is located ahead.
b. The roadway ahead contains numerous curves and should be driven with caution.
c. Roadway ahead is gently curving and requires no extra caution.
d. Hazardous curves will be marked with individual signs.

12. Which of the following signs best indicate that the roadway ahead requires caution and speed reduction to be driven safely? (Circle the best answer)

a.

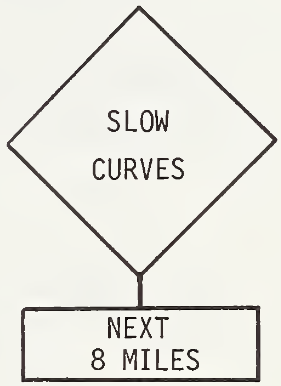


b.



c.

d.

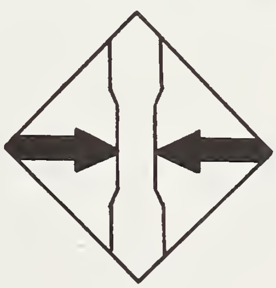


13. For each of the following types of roads, which type of sign is needed, a general warning sign as shown previously, or an individual curve warning sign at each curve? (Check correct answer)

a. General____ Individual____ b. General____ Individual____

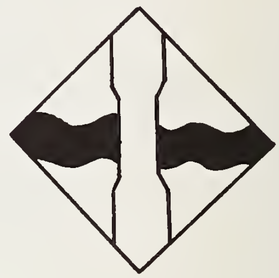
c. General____ Individual____ d. General____ Individual____

14. What is the meaning of the following sign if found on the roadway approach to a bridge? (Circle the best answer)



a. A very short bridge is ahead on the road.
b. Merge to the center of the road.
c. Narrow bridge ahead.
d. A one-lane bridge is ahead.

15. What is the meaning of the following sign if found on the approach to a bridge? (Circle the best answer)

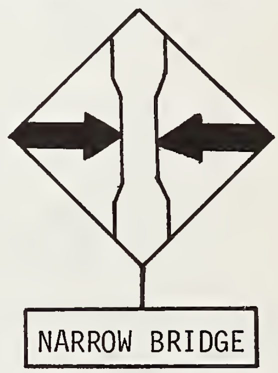


a. Low water crossing ahead on the roadway.
b. Narrow bridge ahead.
c. Narrow roadway ahead.
d. Proceed with caution; hazardous bridge ahead.

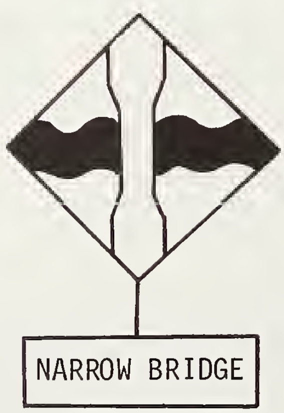
16. Which of the following signs best indicated to the driver that a bridge of limited width is ahead and caution should be exercised? (Circle the <u>best</u> answer)

a.

b.



c.



d.

(OMB 04-S75029)

17. A "Narrow Bridge" sign of some type is needed in which of the following situations? (Check correct answer)

    a. Sign Needed _____ Sign Not Needed _____

    b. Sign Needed _____ Sign Not Needed _____

    c. Sign Needed _____ Sign Not Needed _____

    d. Sign Needed _____ Sign Not Needed _____

18. What would the following pattern of reflectors indicate to you? (Circle the best answer)

    a. Roadway ahead curves to the left.

    b. Roadway ahead hazardous; proceed with caution.

    c. Proceed with caution; roadside outside reflectors is hazardous.

    d. Roadway narrows ahead to the left; proceed with caution.

19. What would the following pattern of reflectors indicate to you? (Circle the best answer)

    a. Roadway narrows ahead.

    b. Roadway narrows in approach to bridge.

    c. Roadside hazardous on either side of roadway.

    d. Roadside clear ahead.

20. At this intersection of two unpaved roads, is this STOP sign needed?

    Yes _____ No _____

21. There is an unpaved road entering this paved State highway from the right. Is a STOP sign needed on the unpaved road?

    Yes _____ No _____

22. Is a STOP sign needed on the road entering from the left at this intersection?

    Yes _____ No _____

23. These two paved roads form a "Y" at their intersection. Is this STOP sign needed?

    Yes _____ No _____

Table 20. Questionnaire responses and chi-square values

Question Number		Number of Responses	Percent of Total	Chi-Square Value	Significance
1.	a.	3	1.1		
	b.	244	90.4		
	c.	31	11.5		
	d.	112	41.5	-	
	e.	252	93.3		
	f.	9	3.3		
	g.	185	68.5		
2.	a.	239	88.5		
	b.	6	2.2		
	c.	267	98.9		
	d.	83	30.7	-	
	e.	6	2.2		
	f.	194	71.9		
	g.	18	6.7		
3.	Yes	70	25.9		
	No	200	74.1	62.59	*
4.	Yes	163	60.4	11.61	*
	No	107	39.6		
5.	a.	254	94.1	114.72	*
	b.	7	2.6		
	c.	8	3.0		
	d.	223	82.6	114.72	*
6.	a.	9	3.3		
	b.	263	97.4	209.79	*
	c.	254	94.1	209.79	*
	d.	9	3.3		
7.	a.	49	17.6		
	b.	55	19.8		
	c.	172	61.9	198.65	*
	d.	2	0.7		

* = Statistical significance at .001 level
** = Statistical significance at .005 level
*** = Statistical significance at .005 level

Table 20. Questionnaire responses and chi-squire values (cont.)

Question Number			Number of Responses	Percent of Total	Chi-Square Value	Significance
8.	Sign		49	17.9		
	Marking		225	82.1	113.05	*
9.	a.	Yes	55	24.8		
		No	167	75.2	56.50	*
	b.	Yes	46	21.5		
		No	168	78.5	69.55	*
	c.	Yes	183	84.3	102.31	*
		No	34	15.7		
	d.	Yes	180	83.3	96.00	*
		No	36	16.7		
10.	a.		16	5.9		
	b.		14	5.2		
	c.		15	5.6		
	d.		225	83.3	490.00	*
11.	a.		6	2.2		
	b.		261	95.2	721.29	*
	c.		3	1.1		
	d.		4	1.5		
12.	a.		8	3.1		
	b.		66	25.6		
	c.		75	29.1		
	d.		109	42.2	39.81	*
13.	a.	General	160	72.4	44.35	*
		Individual	61	27.6		
	b.	General	117	56.0	2.99	***
		Individual	92	44.0		
	c.	General	100	46.5		
		Individual	115	53.5	1.05	***
	d.	General	99	46.3		
		Individual	115	53.75	1.20	***

* = Statistical significance at .001 level
** = Statistical significance at .115 level
*** = Not Significant at .005 level

Table 20. Questionnaire responses and chi-square values (cont.)

Question Number			Number of Responses	Percent of Total	Chi-Square Value	Significance
14.	a.		0	0		
	b.		13	4.7		
	c.		224	81.8	470.66	*
	d.		37	13.5		
15.	a.		87	35.1	13.44	*
	b.		83	33.5		
	c.		7	2.8		
	d.		71	28.6		
16.	a.		60	23.6		
	b.		163	64.2	207.88	*
	c.		27	10.6		
	d.		4	1.6		
17.	a.	Sign Needed	107	48.6		
		Sign Not Needed	113	51.4	0.16	***
	b.	Sign Needed	113	51.1	0.11	***
		Sign Not Needed	108	48.9		
	c.	Sign Needed	194	87.8	126.19	*
		Sign Not Needed	27	12.2		
	d.	Sign Needed	151	68.3	29.69	*
		Sign Not Needed	70	31.7		
18.	a.		185	84.0	409.69	*
	b.		7	3.2		
	c.		14	6.4		
	d.		14	6.4		

* = Statistical Significance at .001 level
** = Statistical Significance at .005 level
*** = Not significant at .005 level

Table 20. Questionnaire responses and chi-square values (cont.)

Question Number		Number of Responses	Percent of Total	Chi-Square Value	Significance
19.	a.	36	16.5		
	b.	153	70.2	237.36	*
	c.	29	13.3		
	d.	0	0		
20.	Yes	66	30.3		
	No	152	69.7	33.93	*
21.	Yes	127	57.2	4.61	***
	No	95	42.8		
22.	Yes	123	55.4	2.59	***
	No	99	44.6		
23.	Yes	136	61.5	11.77	*
	No	85	38.5		

* = Statistical significance at .001 level
** = Statistical significance at .005 level
*** = Not significant at .005 level

REFERENCES

1. Burke, D. "The Cost of Highway Accidents," <u>Texas Transportation Researcher</u>, Volume 7, No. 2, April 1971, pp. 6-7.

2. Oglesby, C. M., Altenhofen, M. J. "Warranted Levels of Improvement for Local Rural Roads," HRB, American Association of State Highway Officials, <u>NCHRP 2-6</u>, 1968.

3. Dart, O. K., Mann, L. "Relationship of Rural Highway Geometry to Accident Rates in Louisiana," <u>HRR, HRB, No. 312,</u> pp. 1-16, 1970.

4. Newby, R. F. "Effectiveness of Speed Limits on Rural Roads and Motorways," <u>Traffic Engineering and Control</u>, Volume 12, No. 8, pp. 424-427, December 1970.

5. Woods, D. L., Rowan, N. J., and Johnson, J. H. "Diagnostic Studies of Highway Visual Communication Systems," Texas Transportation Institute, Bureau of Public Roads.

6. Forbes, T. W., <u>et al</u>. "Letter and Sign Contrast, Brightness, and Size Effects on Visibility," <u>HRR, No. 216</u>, pp. 48-54.

7. Brainard, R. W., Campbell, R. J., and Elkin, E. H. "Design and Interpretability of Road Signs," <u>Journal of Applied Psychology</u>, 1961, Volume 45, pp. 130-136.

8. Dewar, R. E., and Swanson, H. A. "Recognition of Traffic Control Signs," <u>HRR, No. 414,</u> pp. 16-23.

9. Jackman, W. T. "Driver Obedience to Stop and Slow Signs," <u>HRB Bulletin 161</u>, pp. 9-17.

10. Forbes, T. W. "A Method for the Analysis of the Effectiveness of Highway Signs," <u>Journal of Applied Psychology</u>, Volume 23, pp. 669-684, 1939.

11. U.S. Department of the Interior, National Park Service, Park Road Standards, May 1968.

12. HRB "Highway System Classification: A Legal Analysis, Part I." <u>Special Report 42</u>, 1959.

13. HRB "Highway System Classification: A Legal Analysis, Part II." <u>Special Report 85,</u> 1965.

14. King, G. F. and Lunenfeld, H. "Development of Information Requirements and Transmission Techniques for Highway Users," <u>NCHRP, No. 123</u>, 1971.

15. Dart, O. K. and Mann, Jr., L. "Relationship of Rural Highway Geometry to Accidents Rates in Louisiana," HRR, No. 312, pp. 1-16.

16. Kuhn, H. A. J. "Factors Influencing Traffic Generation at Rural Highway Service Areas," HRR, No. 240, pp. 1-11.

17. Miller, Jr., W. J. "Rural Intersection Accidents," HRB, Bulletin 91, pp. 21-29.

18. "A Policy of Geometric Design of Rural Highways," American Association of State Highway Officials, 1965.

19. "Highway Statistics," U.S. Department of Transportation, Federal Highway Administration, 1971.

20. "Manual on Uniform Traffic Control Devices," U.S. Department of Transportation, Federal Highway Administration, 1971.

21. Federal Prison Industries, Inc., #184, 191, Atlanta, Georgia.

22. Taylor, W. C. and Foody, T. J. "Ohio's Curve Delineation Program- An Analysis," Traffic Engineering, Volume 36, No. 9, pp. 41-45, June 1966.

23. Taylor, et al. "Roadway Delineation System," NCHRP 130, Washington, D.C., 1972.

24. Baker, William T. "An Evaluation of the Traffic Conflicts Techniques," Highway Research Record 384, Highway Research Board, 1972.

25. Burke, D. "Highway Accident Costs and Rates in Texas," Research Report 144-1F, Texas Transportation Institute, Texas A&M University, December 1970.

26. Kennedy, N., Kell, J. H., and Hamburger, W. S. Fundamentals of Traffic Engineering, University of California, 1969.

27. Box, P. C. and Associates. "Intersections," Traffic Control Roadway Elements - Their Relationship to Highway Safety, Highway Users Federation, 1970.

28. Winfrey, R. Economic Analysis for Highway, International Textbook Company, 1969.

29. Ritchie, M. L. "Choice of Speed in Driving Through Curves as a Function of Advisory Speed and Curve Signs," Human Factors, December 1972.

30. Perkins, S. R. and Harris, J. I. "Traffic Conflict Characteristics - Accident Potential at Intersections," General Motors Research Laboratories, Warren, Michigan.

31. Ritchie, M. L. "Some Relations Between Visual and Kinesthetic Displays in Normal Driving," Proceedings of 45th Annual NASA-University Conference on Manual Control, Ann Arbor, Michigan, March 21-23, 1968, 459-463.

32. Ashford, F. The Aesthetics of Engineering Design, Business Books Limited, London, England, 1969.

33. Cleveland, D. E. "Traffic Control and Roadway Elements --- Their Relationship to Highway Safety," Chapter 6, Highway Safety Research Institute, University of Michigan, 1970.

FHWA
R&D